Exhibits A-F

65

Receipt Number
563299

UNITED STATES DISTRICT COURT
EASTERN DISTRICT OF MICHIGAN
SOUTHERN DIVISION

MELEA LIMITED, a Gibraltar corporation, **PLASTIC MOLDED TECHNOLOGIES, INC.**, a Michigan corporation, and **FERROMATIK MILACRON MASCHINENBAU GMBH**, a German corporation,

Plaintiffs,

vs.

ENGINEERED PLASTIC COMPONENTS, INC., an Iowa corporation,

Defendant.

Case: 2:07-cv-14529
Assigned To: Cox, Sean F
Referral Judge: Morgan, Virginia M
Filed: 10-23-2007 At 02:58 PM
CMP MELEA LIMITED, ET AL V ENGINEERED PLASTIC COMPONENTS, INC (EW)

JURY TRIAL DEMANDED

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COMPLAINT FOR PATENT INFRINGEMENT
AND JURY DEMAND

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I. THE PARTIES

1. Plaintiff, Melea Limited ("Melea") is a Gibraltar corporation, having an address at First Floor Suites, 38, Irish Town, P.O. Box 466,Gibraltar.

2. Plaintiff, Plastic Molded Technologies, Inc. ("PMT"), is a Michigan corporation, having an address at 51515 Celeste Drive, Shelby Township, Michigan 48315. PMT does business as "GAIN Technologies" and its business includes products and services in the field of gas-assisted plastic injection molding technology. www.gaintechnologies.com.

3. Plaintiff, Ferromatik Milacron Maschinenbau GmbH ("Ferromatik"), is a German corporation, having an address at Riegeler Straße 4, D-79364 Malterdingen, Germany.

4. Defendant, Engineered Plastic Components, Inc. ("EPC"), is an Iowa corporation, having its principal office at 1408 Zimmerman Drive South, Grinnell, Iowa 50112.

5. Defendant EPC has appointed Reza Kargarzadeh as its registered agent for service of process, at 1408 Zimmerman Drive South, Grinnell, Iowa 50112.

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II. JURISDICTION

6. The federal claims pleaded herein arise under the Patent Act, 35 U.S.C. § 1 *et seq.*

7. Subject matter jurisdiction for the federal claims is conferred upon the Court by 28 U.S.C. § 1338(a).

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III. PATENT INFRINGEMENT

8. On April 20, 1993, U. S. Patent No. 5,204,051 ("the '051 patent") was duly and lawfully issued to Christoph Jaroschek for "Process For The Injection Molding Of Fluid-Filled Plastic Bodies." A true and correct copy of the '051 patent is attached as Exhibit A.

9. On June 13, 1995, U. S. Patent No. 5,423,667 ("the '667 patent") was duly and lawfully issued to Christoph Jaroschek for "Apparatus For The Injection Molding Of Fluid-Filled Plastic Bodies." A true and correct copy of the '667 patent is attached at Exhibit B.

10. Ferromatik is the owner by assignment of both the '051 patent and the '667 patent, as evidenced by the records of the Assignment Branch of the United States Patent and Trademark Office.

11. Ferromatik has empowered Melea and PMT (as the authorized representative of Melea) to enforce the '051 patent and the '667 patent, including recovery of damages for past infringement of such patents.

12. On September 21, 1993, U.S. Patent 5,246,646 ("the '646 patent") was duly and lawfully issued to Indra R. Baxi for "Injection Molding Method." A true and correct copy of the '646 patent is at Exhibit C.

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13. Melea Limited is the owner by assignment of the '646 patent, as evidenced by the records of the Assignment Branch of the United States Patent and Trademark Office.

14. On May 5, 1992, U.S. Patent 5,110,533 ("the '533 patent") was duly and lawfully issued to James W. Hendry for "Method For The Use Of Gas Assistance In The Molding Of Plastic Articles To Enhance Surface Quality." A true and correct copy of the '533 patent is at Exhibit D.

15. Melea Limited is the owner by assignment of the '533 patent, as evidenced by the records of the Assignment Branch of the United States Patent and Trademark Office.

16. On May 19, 1992, U.S. Patent 5,114,660 ("the '660 patent") was duly and lawfully issued to James W. Hendry for "Method Of Injection Molding." A true and correct copy of the '660 patent is at Exhibit E.

17. Melea Limited is the owner by assignment of the '660 patent, as evidenced by the records of the Assignment Branch of the United States Patent and Trademark Office.

18. On August 22, 1995, U.S. Patent 5,443,087 ("the '087 patent) was duly and lawfully issued to Colin K. Myles for "Method And System For Controlling A Pressurized Fluid And Valve Assembly For Use Therein." A true and correct copy of the '087 patent is at Exhibit F.

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19. Melea Limited is the owner by assignment of the '087 patent, as evidenced by the records of the Assignment Branch of the United States Patent and Trademark Office.

20. Defendant EPC is a custom molder of plastic products, including plastic products produced using gas-assistance.

21. Defendant EPC supplies gas-assist molded products to the appliance industry, *e.g.*, Whirlpool Corporation of Benton Harbor, Michigan.

22. Defendant EPC transacts business in the State of Michigan in gas-assist molded products produced by the systems and methods covered by the patents-in-suit.

23. Upon information and belief, defendant EPC has entered into contracts for materials, produced using gas-assist systems and methods, to be furnished in the State of Michigan.

24. Defendant EPC uses gas-assist molding equipment supplied by Alliance Gas Systems, Inc. ("Alliance equipment") of 46449 Continental Drive, Chesterfield Township, Michigan 48047.

25. The operation of Alliance equipment in molding of plastic articles with gas-assistance, is covered by the claims of the '646 patent, the '660 patent, and the '087 patent.

26. Defendant EPC has directly infringed the '646 patent, the '660 patent, and the '087 patent, by its operation in the United States of the Alliance equipment in molding of plastic articles with gas-assistance.

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27. Defendant EPC has directly infringed the '646 patent, the '660 patent, and the '087 patent, by its sale and offer for sale in the United States of articles molded with gas-assistance by operation of Alliance equipment.

28. Upon information and belief, subject to the procedure of 35 U.S.C. §295 and other case investigation and discovery, defendant EPC has directly infringed the '533 patent by using in the United States a gas-assist process covered by claim 1 of the '533 patent to mold plastic articles, and selling and offering for sale in the United States gas-assist molded parts made by the process of claim 1 of the '533 patent.

29. Upon information and belief, subject to the procedure of 35 U.S.C. §295 and other cases investigation and discovery, defendant EPC has directly infringed the '051 and '667 patents by using in the United States the process and apparatus covered by the claims of these patents in the gas-assist molding of plastic articles, and selling and offering for sale in the United States the plastic articles made by such claimed process and apparatus.

30. Defendant EPC has actively and knowingly induced and contributed to the direct infringement of the patents-in-suit by others, including its customers for the gas-assist molded articles produced by the systems and processes of the patents-in-suit.

31. Upon information and belief, EPC's infringement has been willful.

32. Plaintiffs have been harmed, both pecuniarily and irreparably, by the infringing conduct of defendant EPC.

33. Defendant's infringing conduct will continue unless enjoined by the Court.

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IV. DEMAND FOR RELIEF

WHEREFORE, plaintiffs demand entry of judgment against defendant granting relief as follows:

A. A determination that EPC has infringed the '051 patent, the '067 patent, the '646, the '533 patent, the '087 patent, and the '660 patent, directly, contributorily, and by inducement;

B. A determination that such infringement has been willful and deliberate;

C. An award of damages adequate to compensate for such infringement;

D. An enhancement of the compensatory damages, up to three (3) times;

E. A determination that this case is "exceptional," in the sense of 35 U.S.C. § 285;

F. An order preliminarily and permanently enjoining EPC, its officers, agents, servants, employees, contractors, suppliers and attorneys, and upon those persons in active concert or participation with them who receive actual notice of the order by personal service or otherwise, from committing further acts of infringement of the '051 patent, the '067 patent, the '646 patent, the '533 patent, the '087 patent, and the '660 patent;

G. An award in favor of plaintiffs, and against defendant, for the costs incurred in bringing and maintaining this action, including reasonable attorneys' fees; and

H. Such further relief as may be just and equitable on the proofs.

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V. JURY DEMAND

Plaintiffs demand trial by jury for all issues so triable.

Respectfully submitted,

By: ______________________

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A

US005204051A

United States Patent [19]

Jaroschek

[11] **Patent Number: 5,204,051**

[45] **Date of Patent: Apr. 20, 1993**

[54] **PROCESS FOR THE INJECTION MOLDING OF FLUID-FILLED PLASTIC BODIES**

[75] Inventor: **Christoph Jaroschek**, Herbolzheim, Fed. Rep. of Germany

[73] Assignee: **Klockner Ferromatik Desma GmbH**, Malterdingen, Fed. Rep. of Germany

[21] Appl. No.: **511,764**

[22] Filed: **Apr. 20, 1990**

[30] **Foreign Application Priority Data**

Apr. 21, 1989 [DE] Fed. Rep. of Germany 3913109

[51] **Int. Cl.**[5] **B29C 45/00; B29C 45/34;** B29D 22/00

[52] **U.S. Cl.** **264/572;** 264/328.8; 264/328.12; 264/328.13; 425/812

[58] **Field of Search** 264/85, 328.8, 328.12, 264/328.13, 500, 572; 425/812

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,044,118	7/1962	Bernhardt et al.	264/85
4,029,454	6/1977	Monnet	425/130
4,101,617	7/1978	Friederich	264/572
4,140,672	2/1979	Kataoka	264/45.1
4,562,990	1/1986	Rose	425/812
4,923,666	5/1990	Yamazaki et al.	264/572
5,028,377	7/1991	Hendry	264/572
5,032,345	7/1991	Hendry	264/572
5,069,859	12/1991	Loren	264/572

FOREIGN PATENT DOCUMENTS

289230	11/1988	European Pat. Off. .	
321117	6/1989	European Pat. Off. .	
1194127	1/1966	Fed. Rep. of Germany .	
2106546	8/1972	Fed. Rep. of Germany	264/572
2445786	4/1979	Fed. Rep. of Germany .	
2800482C	5/1982	Fed. Rep. of Germany .	
2139548B	11/1986	United Kingdom .	

Primary Examiner—Leo B. Tentoni
Attorney, Agent, or Firm—Watson, Cole, Grindle & Watson

[57] **ABSTRACT**

The invention relates to a process for the injection molding of fluid-filled plastic bodies and a device to carry out this process, wherein a pressurized, flowable plastic melt is first injected by means of at least one nozzle into a mold cavity clamped by a two-part or multi-part mold until the mold cavity is completely filled. Next, after cooling of the plastic melt on the mold cavity walls has set in, a pressurized fluid is injected in such manner into the interior of the plastic melt located in the mold cavity that the still melted center of the resulting plastic body is expelled into at least one side cavity arranged outside the mold cavity and connected thereto.

20 Claims, 3 Drawing Sheets

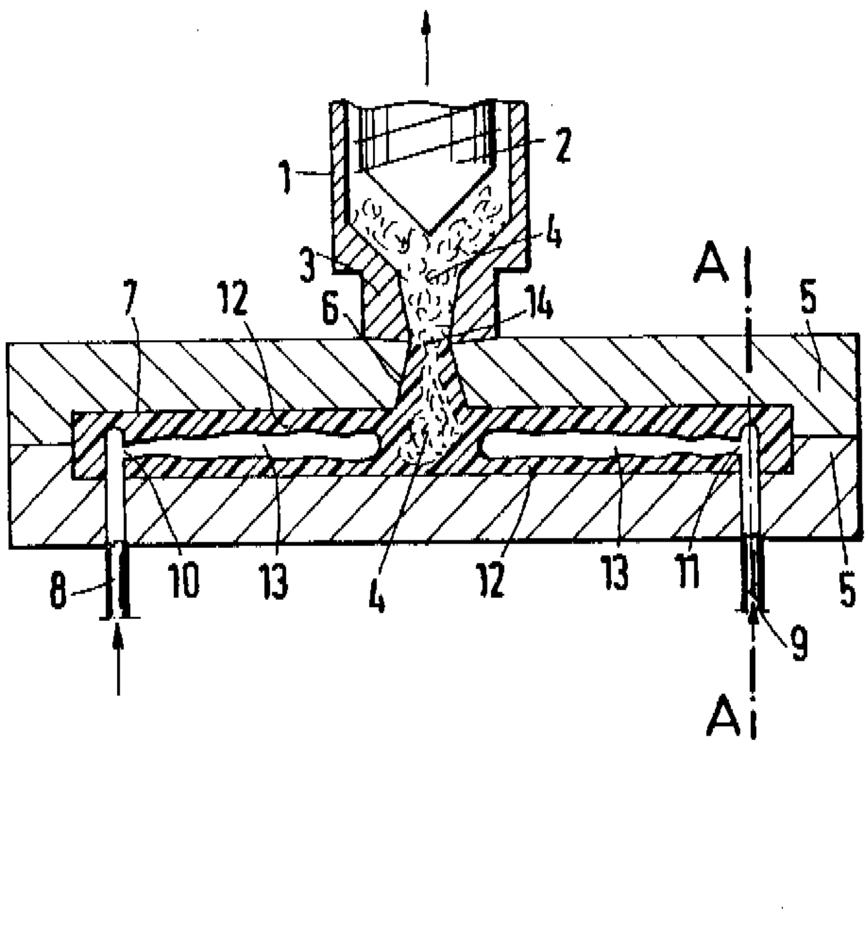

Fig.1

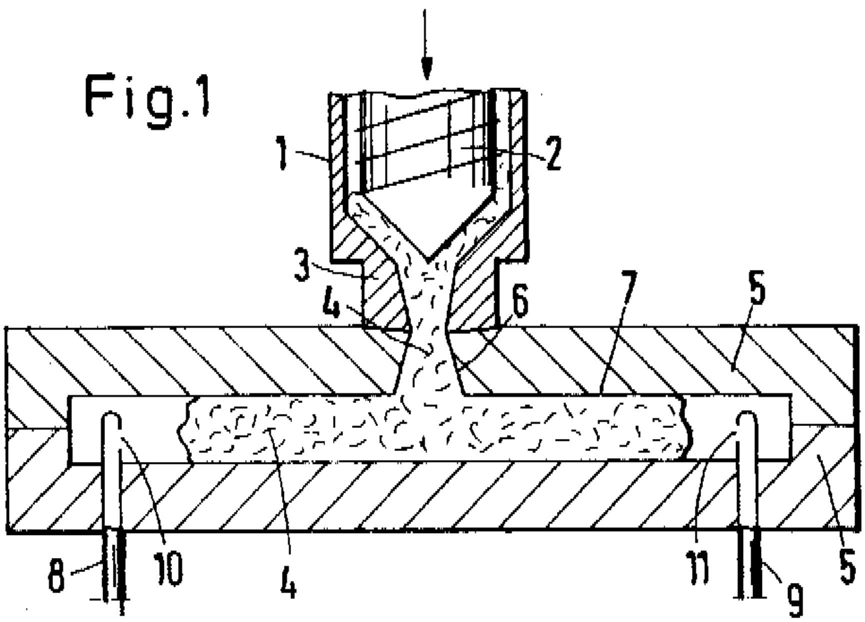

Fig. 2

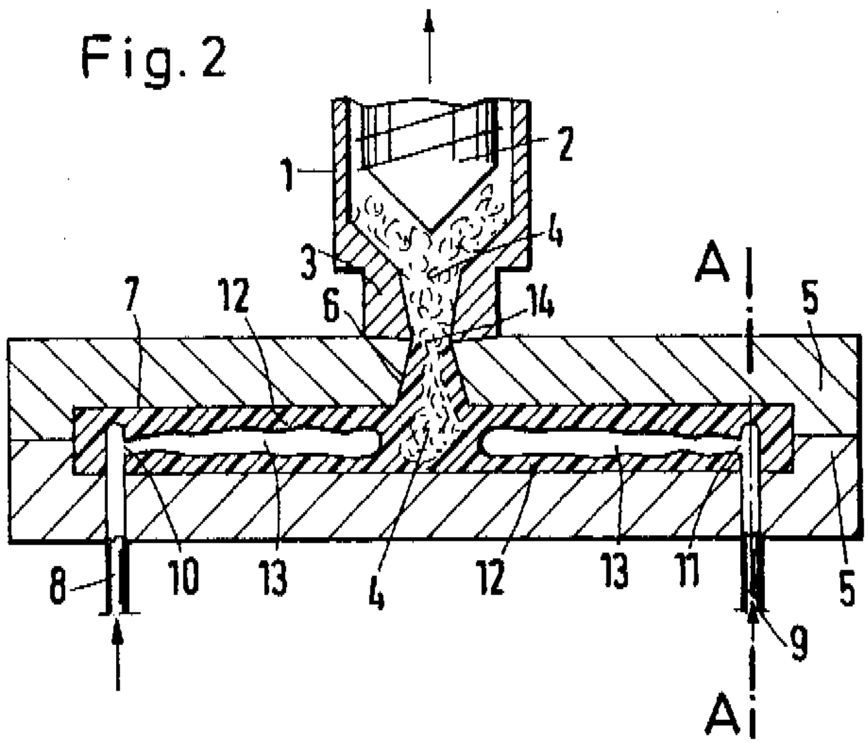

Fig. 3

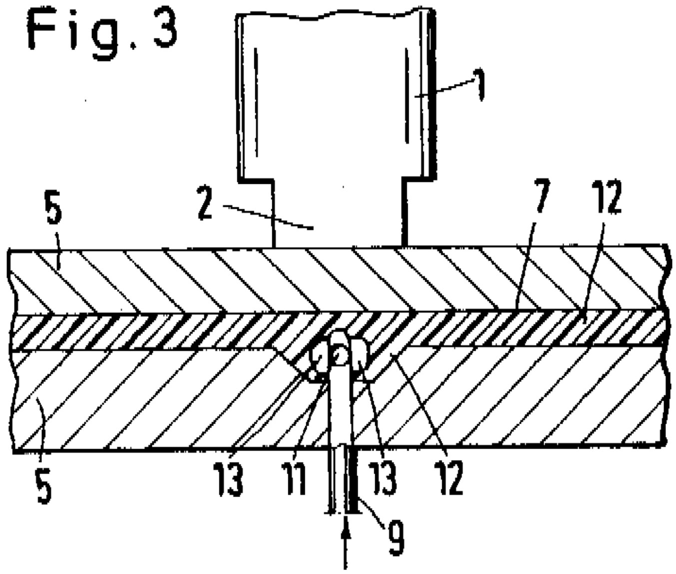

Fig. 4

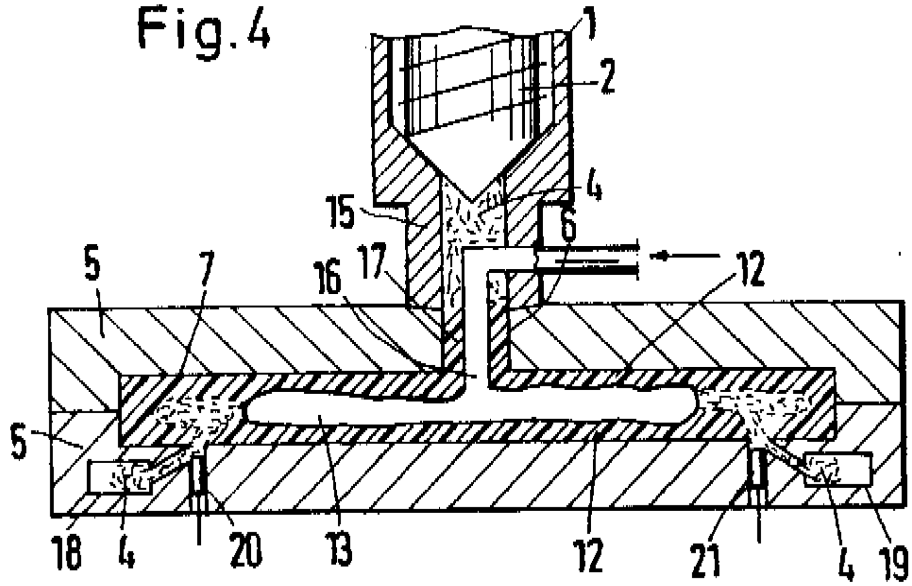

Fig. 5

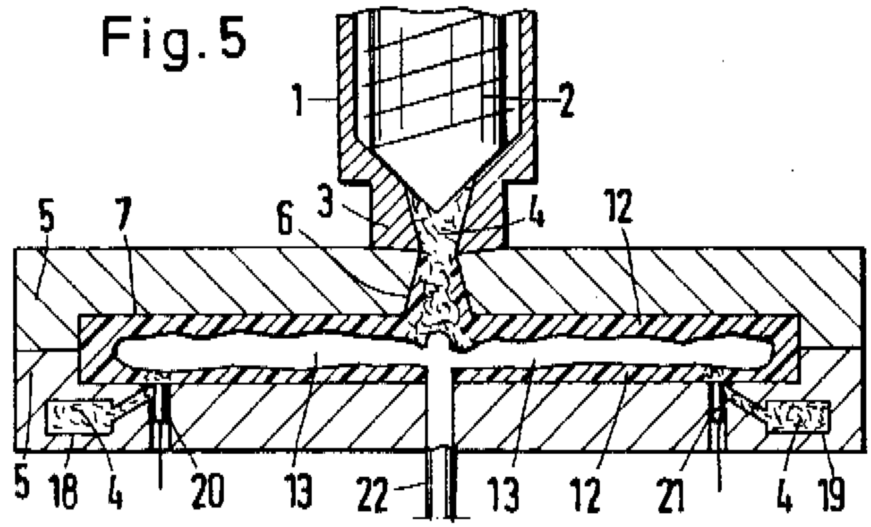
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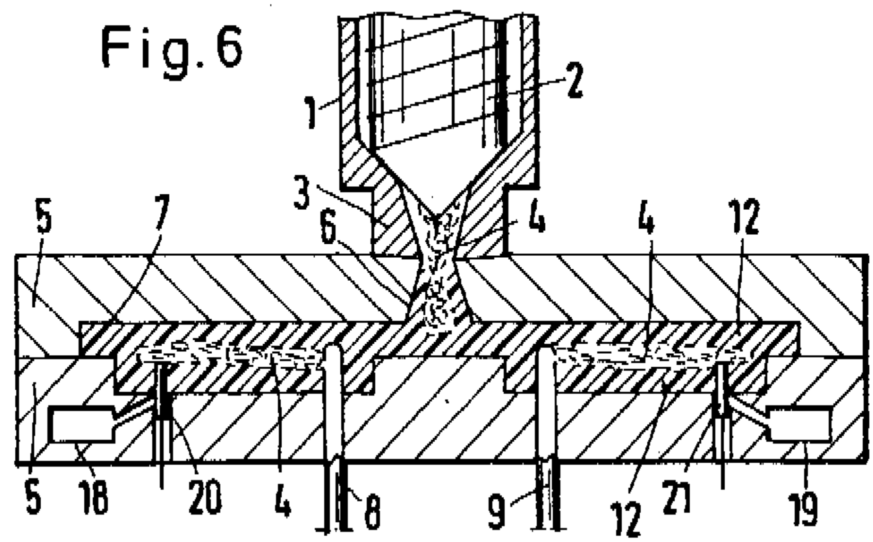
Fig. 6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PROCESS FOR THE INJECTION MOLDING OF FLUID-FILLED PLASTIC BODIES

BACKGROUND OF THE INVENTION

1. Technical Field of the Invention

The present invention relates to a process for the injection molding of fluid-filled plastic bodies and an apparatus to carry out this process.

2. Discussion of the Related Art

A process of this kind is already known from West German patent application DE-05 21 06 546. In this process, a mold cavity for a shoe heel is formed by a two-part mold provided with an ejector punch. First, this cavity is filled partially with plastic melt by means of a nozzle attached to an injection unit to result in a flowable plastic melt. Next, a pressurized fluid—preferably compressed air—is blown by means of a second nozzle, arranged separately from the first, in such a manner into the fluid center of the plastic already located in the mold cavity that the plastic is pressed universally and uniformly against the walls of the mold cavity. The second nozzle is arranged in that half of the mold bearing it in such a manner that it is connected stationarily to it, always points in the direction of the opening and closing motion of the mold, and always attains the fluid center of the plastic when the mold is closed with its mold cavity-sided outlet When the mold is opened, the opening left by the second nozzle in the shoe heel results in a pressure balance between the interior and exterior of the shoe heel. The goal of this process is to economize plastic material and thus minimize the weight of the final product without any impairment to the stability of the final product.

Another process of this kind is disclosed in U.S. Pat. No. 4,101,617, in which the flowable plastic melt and the pressurized fluid—for example air, carbon dioxide or nitrogen—is introduced into the mold cavity by means of a coaxial combination of nozzles. This combination comprises a central nozzle having a circular cross section for the pressurized fluid and an annular nozzle which envelopes the central nozzle for the flowable plastic melt, both running into a joint opening in the mold. In one embodiment, only one part of the whole quantity of the plastic required for the final product is injected into the mold cavity and then the fluid is injected together with the rest of the required plastic. In another embodiment, the plastic and fluid are injected in separate stages. The disclosed result matches that of the aforementioned DE-05 21 06 546. The generated plastic hollow bodies are, for example, double windows, transparent hollow bricks, double walled lighting fixtures and double walled boarder lights. The pressure between the interior and exterior of the plastic hollow bodies i equalized by withdrawing the coaxial combination of nozzles from the opening of the mold before the mold is opened to remove the final product. Alternatively, the pressure is equalized by sealing the gas inlet opening of the hollow body after the body is formed and cooled by pushing a plug-forming quantity of plastic in and boring or piercing the finished hollow body after the mold has been partially or totally opened. The mold cavity can be designed either as unchangeable during the injection molding cycle or as variable during such a cycle by means of at least one suitable lifting punch in the mold.

A process that is similar to the one above is also known from the West German publication DE-PS 28 00 482. This process has the major difference of using a viscous liquid rather than a ga as the fluid to produce a cavity in a plastic hollow body.

Another process of this kind is known from British patent GB-PS 2 139 548, in which a fluid is blown by means of one or more nozzles, which are separated from the nozzle which injects the flowable plastic melt, into the plasticized plastic flowing into the mold cavity. The fluid nozzle or nozzles empties or empty into a runner in the mold and/or also at a suitable point or at suitable points in the actual mold cavity. After the plastic body has cooled in the mold cavity and before the mold is opened, the pressure between the interior—comprising, if the occasion arises, several individual cells—of this plastic body and its exterior is equalized by means of the nozzle(s) installed to introduce the fluid.

In each of these aforementioned processes, only as much plasticized plastic as is necessary to shape the final product is injected into the mold cavity and the fluid must be blown in, whether this blowing takes place simultaneously with the introduction of the flowable plastic melt or later, so long as the flowable plastic melt exhibits initial signs of cooling on the parts of the mold surface with the melt has already made contact. Evidently, in the case of geometrically simple bodies this does not lead to difficulties when fabricating final products with repeatably uniform quality. However, in the case of geometrically complicated bodies with different cross sectional areas vertical to the flow direction of the flowable plastic melt in the mold cavity, for example, in the case of a plate provided with hollow reinforcing ribs on one side, different effects which prevent manufacture of final products with repeatably uniform quality can be expected with the aforementioned methods.

It is to be expected that the flowable plastic melt in the mold cavity, both before and during the blowing of a fluid, flows faster into regions whose cross sections are larger than into regions whose cross sections are smaller and that this effect occurs to a greater degree when a fluid is blown in. Thus, when a fluid is blown in, the flowable plastic melts flows generally into regions whose cross section are greater not only before but rather simultaneously sideways into the adjacent regions whose cross sections are smaller; and in the extreme case a partial reversal in the flow direction of the flowable plastic melt can occur upon reaching the outer wall in conjunction with a break through of the fluid through the outer skin of the plastic body. In any event, disturbing flow marks are produced on the surface of the final product. Only in very special individual cases can this be avoided by fixing the filling picture beforehand, i.e., chronologically changing the behavior of the flow front of the flowable melt and taking the picture into consideration when constructing the mold and, thus, the mold cavity for the geometrically complicated final product.

In addition, for a plastic body with a largely solid construction and only a few, relatively narrow fluid-filled cavities, such a pressure or follow-up pressure must be generated in the entire mold cavity just by means of the pressure of the fluid in these cavities and of the plastic material to be forced out of the cavities so that, following cooling the fluid-filled plastic body exhibits no sink marks on its surface. This, too, can be achieved only in special individual cases when the fluid is prevented from simultaneously breaking through the outer skin of the final product or at least weak points are prevented from occurring in the fabricated parts.

In addition, in the case of final products whose cross sections vary widely or which have special shapes such as curved pipes, only in individual cases can it be repeatedly predetermined what the temperature gradient will be at every individual injection molding cycle, e.g., at a specific cross section through the mold cavity during the simultaneous formation of the wall of the still flowable plastic body and its fluid-filled cavity. However, the actual position of the cavity cross section in the body cross section, for example that of the pipe interior within the pipe body in the region of the pipe curvature, is predefined since the longitudinal axis of a cavity under discussion agrees in essence with the line of the respectively highest temperature of the flowable plastic melt in the flow direction, provided that additional influences of friction and current mechanics do not also have to be considered. A curved pipe manufactured by one of the aforementioned methods can thus exhibit in a cross section in the region of the pipe curvature from one injection molding cycle to another different positions of the pipe inner wall relative to the axis of the pipe and the automatically rotationally symmetrical pipe outer wall and thus have a different wall thickness up to the break-through on the periphery of the pipe.

Therefore, it is an object of the present invention to provide a process and a suitable device to carry out the process wherein fluid-filled plastic bodies having a complicated geometric shape can also be manufactured while avoiding the aforementioned drawbacks and having a faultless surface, in particular without flow marks apart from eventually provided inlet and outlet openings o their subsequent seals.

It is a further object to manufacture bodies having a few, relatively narrow fluid-filled cavities in a largely solid plastic body which show no sink marks in the surface.

Also, it is yet another object to enclose the fluid-filled cavities at predetermined points within the plastic body and with essentially repeatable volume.

Further objects and advantages are apparent from the specification and drawing which follow.

SUMMARY OF THE INVENTION

A special advantage of this invention lies in the fact that to manufacture fluid-filled plastic bodies it provides first of all that the mold cavity in the mold is completely filled with pressurized flowable plastic melt and does not provide that the melted center of such a plastic body be expelled by means of a fluid that is also pressurized until the surface of the plastic body that rests against the mold has already cooled so that, except for eventually provided inlet or outlet openings or their subsequent seals, this surface is produced repeatably without any faults from the start.

Another significant advantage of the invention lies in the fact it does not rule out any point of the mold cavity for the attachment of one or more pairs of nozzles to blow in the fluid and of outlets, connected to side cavities, for the fluid so that with any shape of plastic body regardless of geometrical complexity. Each side cavity is constructed so that after filling a side cavity with a part of the melted center of a plastic body and after the cooling and solidification of this plastic melt, the side cavity can be cleared of this solidified plastic material, or the expelled melted plastic can be used again for the next cycle (in the case of using the injection unit, the injection nozzle and the runner as a side cavity, as discussed below). Each pair of nozzles comprises a fluid blowing nozzle and an associated fluid outlet which can be constructed into a side cavity in order to blow out areas of the body having larger cross sections with fluid. In this process it can also be advantageous for a single nozzle with several outlet openings or even a single outlet opening with several nozzles to interact in pairs.

Another advantage of the invention lies in the fact that at least in special cases it also permits the use of the interior of the configuration(s) of a runner, a nozzle to inject the plastic melt and an associated injection unit as an appropriate side cavity to receive the blown out fluid center of the plastic body when the piston or the screw which works like a piston and belongs to the injection unit is withdrawn in time. In this process the expulsion can be conducted in an advantageous manner such that the portion of the expelled melted center seals every gate opening in such a manner that the wall thickness of the plastic body is not reduced. The remainder of the expelled melted center can be used in the next cycle.

In addition, it has also proven to be advantageous within the scope of the invention that, instead of or in addition to the use of the interior of one or more configurations comprising a runner, a nozzle to inject plastic melt and an associated injection unit as side cavity(ies), the interior of one cavity or several cavities arranged outside the mold cavity in the mold but connected to the mold cavity is used as an appropriate side cavity or cavities, wherein each of these connections is equipped with means to arbitrarily open and close these connections. In this manner the flexibility with respect to the aforementioned possibilities of arbitrarily adapting pairs of fluid blowing nozzles and fluid outlet openings in the mold cavity is significantly facilitated and at the same time care is taken that with simple and readily controllable means the surface of the plastic body can be built up, its melted center can be blown out and the terminating plug-like outlet opening(s) can be sealed with the remainder of the melted center.

The embodiments and the manner in which the subject matter of the invention functions are explained in detail with respect to the following drawings and detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of an injection molding machine, which is illustrated schematically during a complete filling of the mold cavity with flowable plastic melt;

FIG. 2 is a sectional view of the injection molding machine of FIG. 1 following cooling of the surface of the plastic body and during the expulsion of the melted center of the plastic body into a side cavity, formed by the interior of the runner, the nozzle and the injection unit;

FIG. 3 is a sectional view taken along line A—A of FIG. 2;

FIG. 4 is a sectional view of an injection molding machine of the invention shown schematically in which the fluid expels the melted center of the plastic body by means of a nozzle which is arranged concentrically in a nozzle to inject the plastic melt into separate, side cavities that are connected to the mold cavity;

FIG. 5 is a sectional view of a schematically illustrated injection molding machine of the invention in which the fluid has expelled the melted center of the plastic body by means of a single nozzle to inject the fluid into several separate, side cavities connected to the mold cavity; and

FIG. 6 is a sectional view of a schematically illustrated injection molding machine of the invention in which the fluid will expel the melted center of the plastic body by means of several pairs of elements, each pair comprising a nozzle to inject the fluid and an associated side cavity comprising several defined subregions of the plastic body.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a schematic drawing of an injection molding machine of the invention with an injection unit 1 (which is only shown as a fragment) in which an extruder screw 2 is provided to generate significant changes in pressure by a piston-like motion in the axial direction in addition to rotational motion. A nozzle 3 is provided to inject a flowable plastic melt 4. A multi-part mold 5 is also provided which in the illustrated case has two parts and has a runner 6 and a mold cavity 7 defined by the mold walls. In addition, the mold 5 is equipped with additional nozzles 8, 9 to inject a fluid into the mold cavity 7 which is completely filled beforehand with free-flowing plastic melt 4. These nozzles 8, 9 can be connected in the conventional manner either stationarily to a part of the tool or can be moved with respect to the part of the tool and in this embodiment are located a maximum distance from plastic melt nozzle 3.

FIG. 1 shows the injection molding machine in a stage in which the mold cavity 7 has not yet been completely filled with flowable plastic melt 4, a state which is indicated by the arrow marking the direction of the axial motion of the extruder screw 2. The nozzles 8, 9 which inject a fluid, for example compressed air, compressed nitrogen, or a pressurized suitable liquid, are not yet enveloped by the plastic melt 4. In the nozzles a fluid pressure, which just compensates for the pressure in the mold cavity 7 in the region of the nozzle openings 10, 11, is maintained in this stage.

FIG. 2 shows the injection molding machine of FIG. 1 at a later point in an injection molding cycle in which the mold cavity 7 had already been completely filled with flowable plastic melt 4 and the surface 12 of the plastic melt 4 resting against the walls of the mold cavity 7 has already set after cooling. At this point in time, on the one hand, a pressurized fluid 13 is injected through the nozzles 8, 9 into the flowable plastic melt 4 which has not set yet, i.e., in the melted center of the resulting plastic body, as indicated with the arrows under nozzles 8, 9. On the other hand, at the same time the extruder screw 2 is pulled away from the mold 5 as indicated by the arrow to increase an effective volume so that the interior of the runner 6, nozzle 3 and injection unit 1 forms a side cavity 14, which lies outside the mold cavity 7 but is connected to it, to receive the expelled free-flowing plastic melt 4. Each side cavity is constructed s that after filling a side cavity with a part of a melted center of a plastic body and after cooling and solidification of this plastic melt, the side cavity can be cleared of this solidified plastic material, or the expelled melted plastic can be used again for the next cycle (in the case of using the injection unit, the injection nozzle and the runner as a side cavity). Thus, the injection and expelling of the plastic melt occurs in substantially opposite directions in this embodiment.

The injection of the fluid 13 is not terminated until a portion of the plastic melt 4 interior to be expelled forms a plug in front of the runner 6 having the same wall thickness as the cooled surface 12. The plug supplements the cooled surface 12 which is already present in its vicinity within the mold cavity 7 to form a plastic body with a smooth and continuous outer surface without any reduction in wall thickness. The runner 6 can have a cross sectional area which is adapted for the dual function of a gate and an expulsion opening and accordingly may be larger than a conventional runner which only functions as a gate. After the final setting of the plastic body that is produce and prior to opening the mold, the pressure between the fluid-filled interior of the plastic body and the atmosphere can be balanced, for example, by means of one or both of the nozzles 8, 9. The remainder of the expelled plastic melt which does not form the plug is available for the next molding cycle.

FIG. 3 shows a sectional view taken along line A—A of FIG. 2, which assumes that the plastic body to be produced is a plate-like structure with reinforcing ribs, wherein the ribs are designed as hollow ribs. In accordance with the invention, it does not matter at this point whether the body has a rectangular shape with parallel running reinforcing ribs or a round or oval shape with radially running ribs. In particular, it should also be recognized here, in addition to FIG. 2, that in the case of complicated geometric shapes there exists the possibility of being able to define very accurately by means of the process and apparatus of the invention selected regions of a plastic body that can be produced in order to fill it with a pressurized fluid

FIG. 4 shows another embodiment of an injection molding machine of the invention in a stage corresponding to that of FIG. 2 in which the flowable plastic melt 4 and the pressurized fluid 13 are injected one after another by means of a coaxial nozzle 15 having an inner nozzle 16 having a circular cross section to inject the pressurized fluid 13 and an outer annular nozzle 17 to inject the free-flowing plastic melt 4 into the mold cavity 7. Following the injection of the flowable plastic melt 4, the extruder screw 2 remains inoperative in its foremost position; the still flowable plastic melt 4 of the melted center of the plastic body is expelled into the demoldable side cavities 18, 19, which are arranged outside the mold cavity 7 and connected thereto and whose connections to the mold cavity 7 can be opened and closed by means of stuffers 20, 21 that can be actuated between open and closed positions. The side cavities 18, 19 are located at a maximum distance from coaxial nozzle 15 in accordance with requirements imposed on the shape of the resulting plastic body. Thus, the injection and expulsion of the plastic melt occurs in substantially the same direction. Following the expulsion of the still flowable plastic melt 4, the side cavities 18, 19 can be closed in time and in such a manner that the rest of the plastic melt forms a plug which aligns with the set surface 12 of the plastic body over the stuffers 20, 21 and whose height corresponds to at least the wall thickness of the already formed set surface 12 of the plastic body.

FIG. 5 shows another embodiment of an injection molding machine of the invention, which differs significantly from the above embodiments in that the still flowable plastic melt 4 is expelled with a single nozzle 22 separated from the plastic injecting nozzle 3. Nozzle 22 is aligned with plastic melt nozzle 3 to inject pressurized fluid in the horizontal direction of the plastic melt and is located at an opposite mold wall from nozzle 3. Nozzle 22 injects the pressurized fluid 13 into several side cavities 18, 19 located at a maximum distance from the oppositely arranged nozzles in accordance with the requirements imposed on the shape of the plastic body. In this figure a stage of an injection molding cycle is shown in which the expulsion of the still flowable plastic melt 4 from the melted center of the plastic body has just terminated. The stuffers 20, 21 are moved into a closing position that aligns with the surface of the mold cavity 7. With the remainder of the plastic melt 4, a plug, whose height corresponds to the wall thickness of the set surface 12 of the plastic body that envelops the plug, is produced above each stuffer 20, 21.

In contrast, FIG. 6 shows an embodiment which uses several pairs of nozzles 8, 9 to inject the pressurized fluid 13 and uses associated side cavities 18, 19 to provide only individual regions of a plastic body, for example interrupted reinforcing ribs at a plate-shaped structure, in a selected manner with an inner filling of pressurized fluid 13. The nozzles 8, 9 are located near nozzle 3 and direct the pressurized fluid toward associated side cavities 18, 19 located at a maximum distance from the plastic melt nozzle 3 in accordance with geometric considerations of the desired plastic body. The injection molding machine is shown in a stage of an injection molding cycle in which the setting of the surface 12 of the plastic body has advanced to such a degree that the still flowable plastic melt 4 is about to be directly expelled into the side cavities 18, 19. The stuffers 20, 21 are still positioned in such a manner in the mold cavity 7 so that they extend into the mold, are enclosed by already set material of the surface 12 and, upon release of the connections from the mold cavity 7 to the side cavities 18, 19, produce defined openings in the set surface 12. The pressure of the fluid in the nozzles 8, 9 compensates just the pressure in the mold cavity 7 in front of the nozzle openings. Following the end of the expulsion phase and the complete cooling of the fluid-filled plastic body and prior to the opening of the mold 5, here, as in all of the preceding cases, the pressure between the fluid-filled interior of the plastic body and the atmosphere can be balanced, for example, via the nozzles 8, 9 to inject the pressurized fluid and, if desired, a material exchange with the atmosphere effected.

In the preceding embodiments, pressurized fluid nozzles 8, 9 and 22 may be designed driven in order to advance into and retract out of the mold cavity with respect to a cavity wall and therefore be positionable to effect proper formation of plastic body. By retracting the fluid nozzle out of mold cavity 7, a direct channel to the atmosphere is formed to equalize pressure. This pressure equalization can also be accomplished by means of a suitable change-over valve of conventional type located in the supply line to one of the pressurized fluid nozzles.

Many modifications and improvements will be apparent to one skilled in the art without departing from the scope of the present invention as defined in the following claims.

We claim:

1. A process for the injection molding of fluid filled plastic bodies, comprising the steps of:

- injecting a pressurized, flowable plastic melt into an interior of a mold cavity defined by walls to completely fill the mold cavity;
- cooling part of the plastic melt along the walls, thereby providing an interior of flowable, plastic melt; then
- providing at least one side cavity in communication with the mold cavity;
- injecting a pressurized fluid into the interior of flowable, plastic melt formed by cooling part of the plastic melt along the walls;
- expelling the interior of flowable, plastic melt into the at least one side cavity via the injected pressurized fluid; and
- separating the flowable, plastic melt expelled into the at least one side cavity from the fluid filled plastic body in the mold cavity.

2. The process according to claim 1, wherein said providing step further comprises providing at least one plastic melt nozzle for injecting the plastic melt, an associated runner space between the at least one melt nozzle and the mold cavity, and an associated injection unit.

3. The process according to claim 2, wherein said expelling step comprises withdrawing an extruder screw of the injection unit to increase the volume of the associated runner space to form a plug of expelled flowable plastic melt adjacent the at least one plastic melt nozzle.

4. The process according to claim 1, further comprising the step of closing the at least one side cavity to form a plug of cooled plastic at the at least one side cavity.

5. The process according to claim 4, wherein said closing step is timed with the expelling step to form a plug which has a thickness equal to a thickness of the previously cooled plastic melt along the walls such that the plug is aligned with the outer surface of the plastic body to form a smooth outer surface.

6. The process according to claim 2, further comprising the step of closing the at least one side cavity to form a plug of cooled plastic at the at least one side cavity.

7. The process according to claim 6, wherein said closing step is timed with the expelling step to form a plug which has a thickness equal to a thickness of the previously cooled plastic melt along the walls such that the plug is aligned with the outer surface of the plastic body to form a smooth outer surface.

8. The process according to claim 3, further comprising the step of closing the at least one side cavity to form a plug of cooled plastic at the at least one side cavity.

9. The process according to claim 8, wherein said closing step is timed with the expelling step to form a plug which has a thickness equal to a thickness of the previously cooled plastic melt along the walls such that the plug is aligned with the outer surface of the plastic body to form a smooth outer surface.

10. The process according to claim 1, wherein said plastic melt injecting and expelling steps occur in substantially the same direction.

11. The process according to claim 1, wherein said plastic melt injecting and expelling steps occur in substantially opposite directions.

12. The process according to claim 1, further comprising balancing the pressure of the interior of the plastic body with surrounding atmosphere after said expelling step.

13. A process as in claim 1, further comprising closing said at least one side cavity with a stuffer after said expelling step.

14. A process as in claim 13, wherein said stuffer is moved into alignment with a surface of the mold cavity.

15. A process as in claim 1, wherein said pressurized fluid is injected into said interior in a direction perpendicular to a direction of injection of the flowable plastic melt into the mold cavity.

16. A process as in claim 1, wherein said pressurized fluid is injected into said interior in the same direction as a direction of injection of flowable plastic melt into the mold cavity.

17. A process as in claim 1, wherein said pressurized fluid is injected into said interior in an opposite direction as a direction of injection of flowable plastic melt into the mold cavity.

18. A process for the injection molding of fluid filled plastic bodies, comprising the steps of:

providing a mold cavity having walls and an interior defined by said walls;

injecting a pressurized, flowable plastic melt into the interior of the mold cavity to completely fill the mold cavity;

providing at least one side cavity in communication with the mold cavity through a communication means; then

cooling part of the plastic melt along the walls, thereby providing an interior of flowable, plastic melt;

injecting a pressurized fluid into the interior of flowable, plastic melt formed by cooling part of the plastic melt along the walls;

expelling the interior of flowable, plastic melt into the at least one side cavity via the injected pressurized fluid; and

interrupting communication between the mold cavity and the side cavity with a means to selectively interrupt the communication means.

19. A process for the injection molding of fluid filled plastic bodies, comprising the steps of:

providing a mold cavity having walls and an interior defined by said walls;

providing at least one side cavity in communication with the mold cavity through a communication means;

interrupting communication between the mold cavity and the side cavity with a means to selectively interrupt the communication means;

injecting a pressurized, flowable plastic melt into the interior of the mold cavity to completely fill the mold cavity;

cooling part of the plastic melt along the walls, thereby providing an interior of flowable, plastic melt;

providing a communication between said mold cavity and said side cavity with said means to selectively interrupt the communication means;

injecting a pressurized fluid into the interior of flowable, plastic melt formed by cooling part of the plastic melt along the walls;

expelling the interior of flowable, plastic melt into the at least one side cavity via the injected pressurized fluid; and

separating the flowable, plastic melt expelled into the at least one side cavity from the fluid filled plastic body in the mold cavity.

20. A process as in claim 18, wherein said step of separating the flowable, plastic melt expelled into the at least one side cavity from the fluid filled plastic body in the mold cavity comprises interrupting communication between said at least one side cavity and said mold cavity with said means to selectively interrupt the communication means.

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US005423667A

United States Patent [19]

Jaroschek

[11] **Patent Number:** 5,423,667

[45] **Date of Patent:** Jun. 13, 1995

[54] **APPARATUS FOR THE INJECTION MOLDING OF FLUID-FILLED PLASTIC BODIES**

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[73] Assignee: **Ferromatik Milacron Maschinenbau GmbH**, Malterdingen, Germany

[21] Appl. No.: **178,607**

[22] Filed: **Jan. 7, 1994**

Related U.S. Application Data

[60] Continuation of Ser. No. 825,273, Jan. 24, 1992, abandoned, which is a division of Ser. No. 511,764, Apr. 20, 1990, Pat. No. 5,204,051.

[30] **Foreign Application Priority Data**

Apr. 21, 1989 [DE] Germany 39 13 109.2

[51] **Int. Cl.**^{6} **B29C 45/16**

[52] **U.S. Cl.** **425/130**; 264/328.12; 264/572; 425/572; 425/812

[58] **Field of Search** 425/130, 572, 588, 812; 264/85, 28.8, 328.12, 328.13, 500, 572

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Primary Examiner—Tim Heitbrink
Attorney, Agent, or Firm—Stephen H. Friskney

[57] **ABSTRACT**

A device for producing moldings of plastic material having a cavity therein filled with a fluid comprises a mold cavity, an injector for injecting flowable plastic into the mold cavity, an injector for injecting a pressurized fluid into an interior portion of the plastic, and a side cavity connected to the mold to receive flowable plastic melt expelled by the injected pressurized fluid. The side cavity may be randomly lockable and may comprise a closing stuffer which rests flush with respect to the mold cavity interior walls.

16 Claims, 3 Drawing Sheets

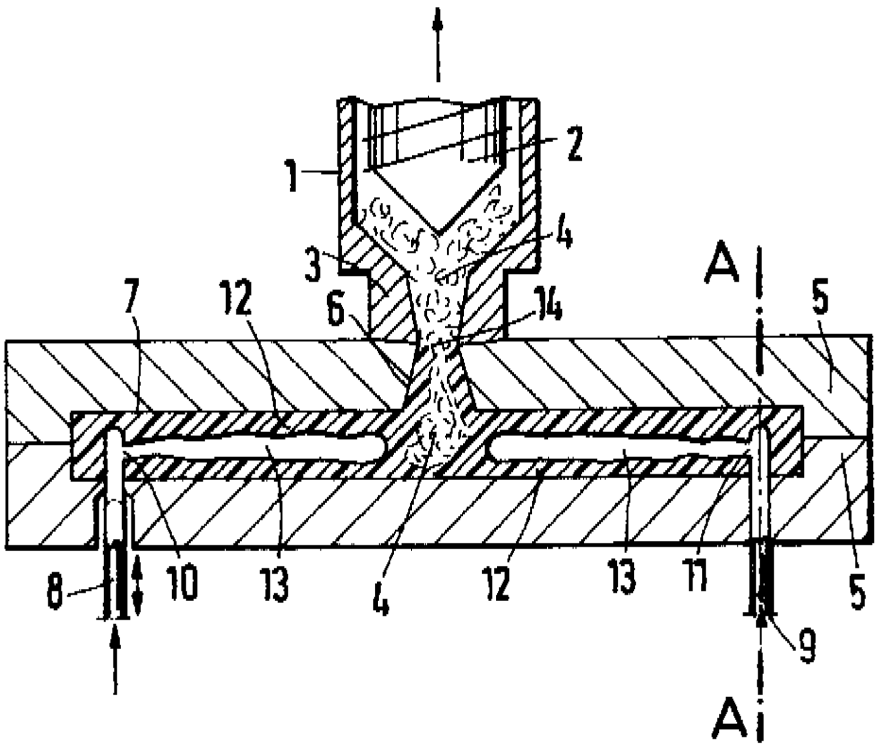

Fig.1

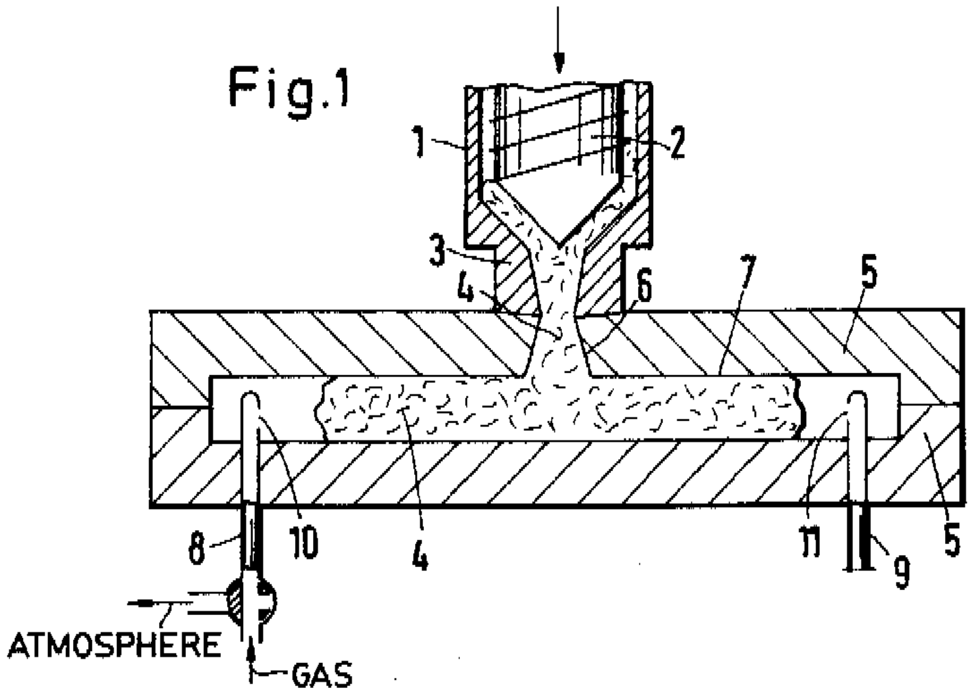
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Fig.2

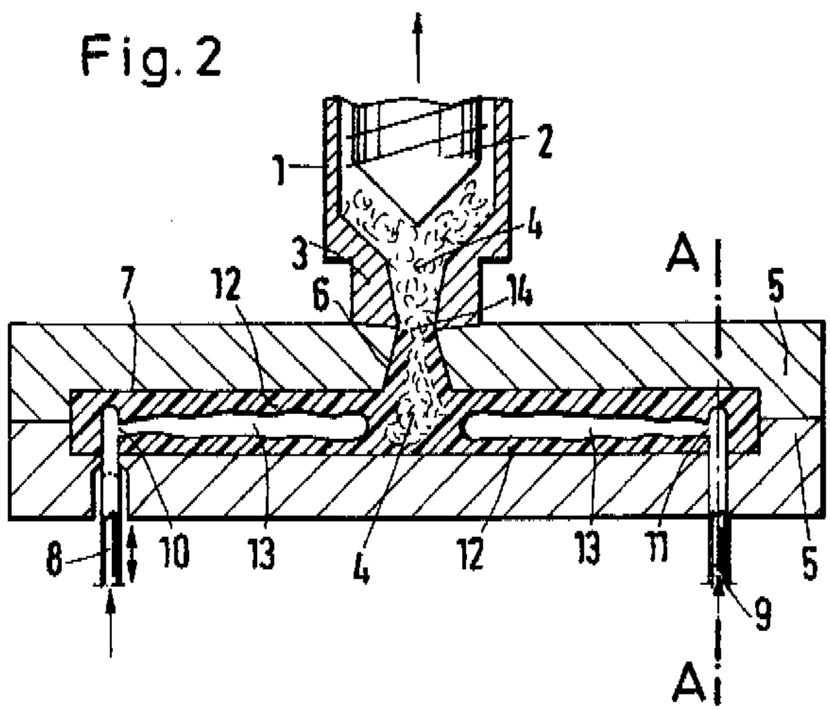
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Fig. 3

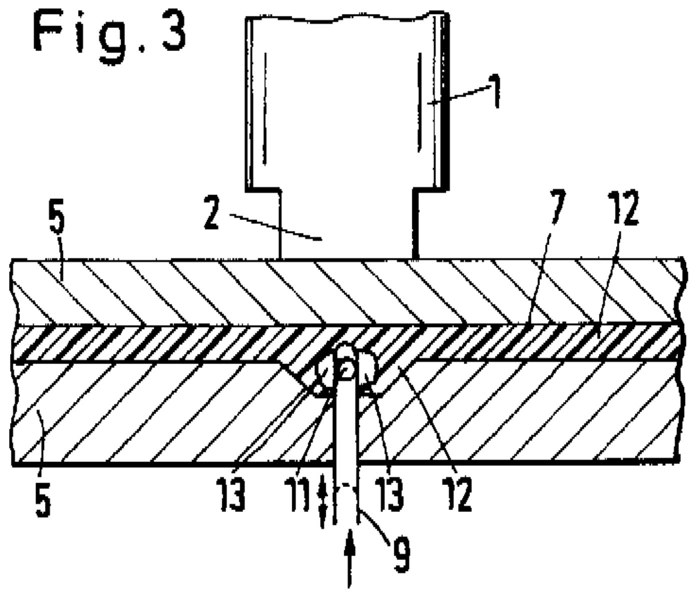

Fig. 4

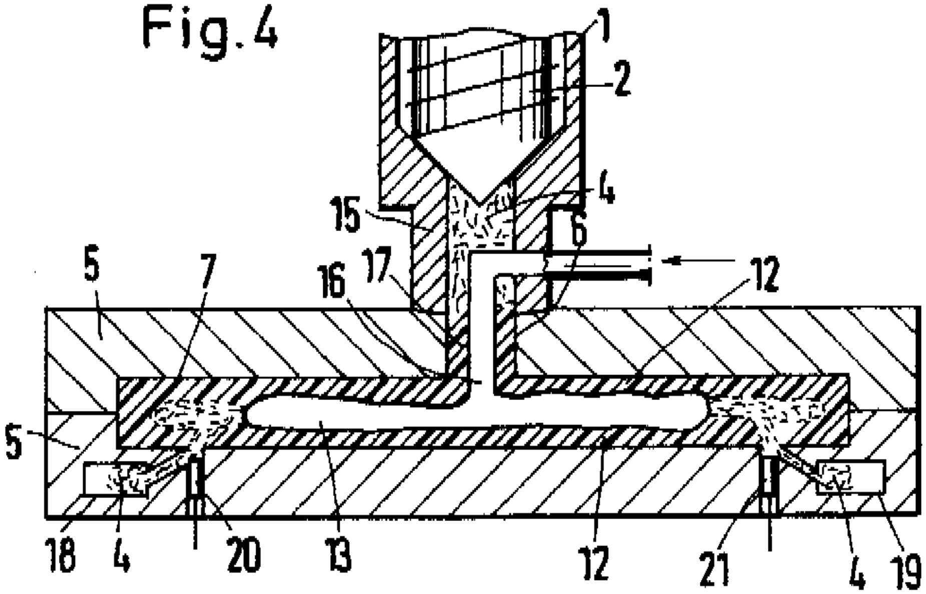

Fig. 5

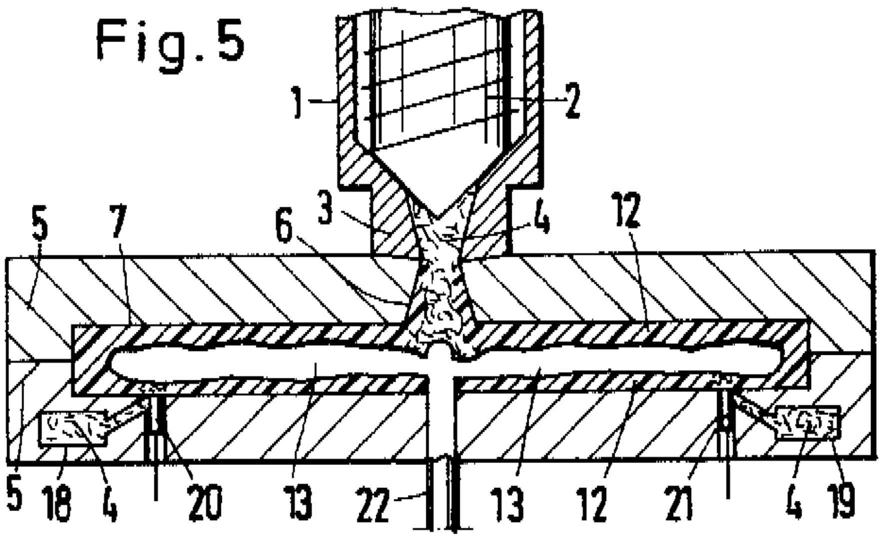
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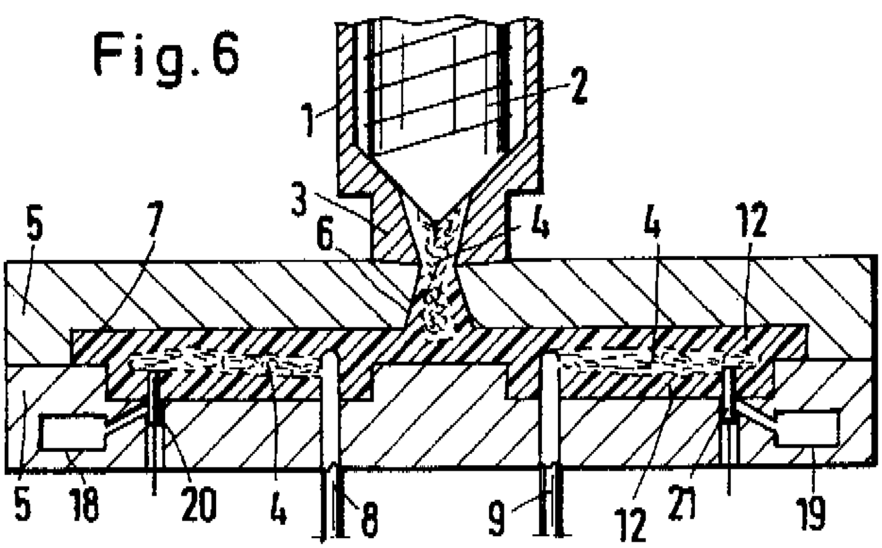
Fig. 6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APPARATUS FOR THE INJECTION MOLDING OF FLUID-FILLED PLASTIC BODIES

This is a Continuation of application Ser. No. 07/825,273 filed Jan. 24, 1992, now abandoned, which in turn is a divisional of application Ser. No. 07/511,764, filed Apr. 20, 1990 now U.S. Pat. No. 05,204,051.

TECHNICAL FIELD OF THE INVENTION

The present invention relates to a process for the injection molding of fluid-filled plastic bodies and an apparatus to carry out this process.

DISCUSSION OF THE RELATED ART

A process of this kind is already known from West German patent application DE-05 21 06 546. In this process, a mold cavity for a shoe heel is formed by a two-part mold provided with an ejector punch. First, this cavity is filled partially with plastic melt by means of a nozzle attached to an injection unit to result in a flowable plastic melt. Next, a pressurized fluid—preferably compressed air—is blown by means of a second nozzle, arranged separately from the first, in such a manner into the fluid center of the plastic already located in the mold cavity that the plastic is pressed universally and uniformly against the walls of the mold cavity. The second nozzle is arranged in that half of the mold bearing it in such a manner that it is connected stationarily to it, always points in the direction of the opening and closing motion of the mold, and always attains the fluid center of the plastic when the mold is closed with its mold cavity-sided outlet. When the mold is opened, the opening left by the second nozzle in the shoe heel results in a pressure balance between the interior and exterior of the shoe heel. The goal of this process is to economize plastic material and thus minimize the weight of the final product without any impairment to the stability of the final product.

Another process of this kind is disclosed in U.S. Pat. No. 4,101,617, in which the flowable plastic melt and the pressurized fluid—for example air, carbon dioxide or nitrogen—is introduced into the mold cavity by means of a coaxial combination of nozzles. This combination comprises a central nozzle having a circular cross section for the pressurized fluid and an annular nozzle which envelopes the central nozzle for the flowable plastic melt, both running into a joint opening in the mold. In one embodiment, only one part of the whole quantity of the plastic required for the final product is injected into the mold cavity and then the fluid is injected together with the rest of the required plastic. In another embodiment, the plastic and fluid are injected in separate stages. The disclosed result matches that of the aforementioned DE-05 21 06 546. The generated plastic hollow bodies are, for example, double windows, transparent hollow bricks, double walled lighting fixtures and double walled boarder lights. The pressure between the interior and exterior of the plastic hollow bodies is equalized by withdrawing the coaxial combination of nozzles from the opening of the mold before the mold is opened to remove the final product. Alternatively, the pressure is equalized by sealing the gas inlet opening of the hollow body after the body is formed and cooled by pushing a plug-forming quantity of plastic in and boring or piercing the finished hollow body after the mold has been partially or totally opened. The mold cavity can be designed either as unchangeable during the injection molding cycle or as variable during such a cycle by means of at least one suitable lifting punch in the mold.

A process that is similar to the one above is also known from the West German publication DE-PS 28 00 482. This process has the major difference of using a viscous liquid rather than a gas as the fluid to produce a cavity in a plastic hollow body.

Another process of this kind is known from British patent GB-PS 2 139 548, in which a fluid is blown by means of one or more nozzles, which are separated from the nozzle which injects the flowable plastic melt, into the plasticized plastic flowing into the mold cavity. The fluid nozzle or nozzles empties or empty into a runner in the mold and/or also at a suitable point or at suitable points in the actual mold cavity. After the plastic body has cooled in the mold cavity and before the mold is opened, the pressure between the interior—comprising, if the occasion arises, several individual cells—of this plastic body and its exterior is equalized by means of the nozzle(s) installed to introduce the fluid.

In each of these aforementioned processes, only as much plasticized plastic as is necessary to shape the final product is injected into the mold cavity and the fluid must be blown in, whether this blowing takes place simultaneously with the introduction of the flowable plastic melt or later, so long as the flowable plastic melt exhibits initial signs of cooling on the parts of the mold surface with the melt has already made contact. Evidently, in the case of geometrically simple bodies this does not lead to difficulties when fabricating final products with repeatably uniform quality. However, in the case of geometrically complicated bodies with different cross sectional areas vertical to the flow direction of the flowable plastic melt in the mold cavity, for example, in the case of a plate provided with hollow reinforcing ribs on one side, different effects which prevent manufacture of final products with repeatably uniform quality can be expected with the aforementioned methods.

It is to be expected that the flowable plastic melt in the mold cavity, both before and during the blowing of a fluid, flows faster into regions whose cross sections are larger than into regions whose cross sections are smaller and that this effect occurs to a greater degree when a fluid is blown in. Thus, when a fluid is blown in, the flowable plastic melts flows generally into regions whose cross section are greater not only before but rather simultaneously sideways into the adjacent regions whose cross sections are smaller; and in the extreme case a partial reversal in the flow direction of the flowable plastic melt can occur upon reaching the outer wall in conjunction with a break through of the fluid through the outer skin of the plastic body. In any event, disturbing flow marks are produced on the surface of the final product. Only in very special individual cases can this be avoided by fixing the filling picture beforehand, i.e., chronologically changing the behavior of the flow front of the flowable melt and taking the picture into consideration when constructing the mold and, thus, the mold cavity for the geometrically complicated final product.

In addition, for a plastic body with a largely solid construction and only a few, relatively narrow fluid-filled cavities, such a pressure or follow-up pressure must be generated in the entire mold cavity just by means of the pressure of the fluid in these cavities and of the plastic material to be forced out of the cavities so that, following cooling, the fluid-filled plastic body exhibits no sink marks on its surface. This, too, can be achieved only in special individual cases when the fluid is prevented from simultaneously breaking through the outer skin of the final product or at least weak points are prevented from occurring in the fabricated parts.

In addition, in the case of final products whose cross sections vary widely or which have special shapes such as curved pipes, only in individual cases can it be repeatedly predetermined what the temperature gradient will be at every individual injection molding cycle, e.g., at a specific cross section through the mold cavity during the simultaneous formation of the wall of the still flowable plastic body and its fluid-filled cavity. However, the actual position of the cavity cross section in the body cross section, for example that of the pipe interior within the pipe body in the region of the pipe curvature, is predefined since the longitudinal axis of a cavity under discussion agrees in essence with the line of the respectively highest temperature of the flowable plastic melt in the flow direction, provided that additional influences of friction and current mechanics do not also have to be considered. A curved pipe manufactured by one of the aforementioned methods can thus exhibit in a cross section in the region of the pipe curvature from one injection molding cycle to another different positions of the pipe inner wall relative to the axis of the pipe and the automatically rotationally symmetrical pipe outer wall and thus have a different wall thickness up to the break-through on the periphery of the pipe.

Therefore, it is an object of the present invention to provide a process and a suitable device to carry out the process wherein fluid-filled plastic bodies having a complicated geometric shape can also be manufactured while avoiding the aforementioned drawbacks and having a faultless surface, in particular without flow marks apart from eventually provided inlet and outlet openings or their subsequent seals.

It is a further object to manufacture bodies having a few, relatively narrow fluid-filled cavities in a largely solid plastic body which show no sink marks in the surface.

Also, it is yet another object to enclose the fluid-filled cavities at predetermined points within the plastic body and with essentially repeatable volume.

Further objects and advantages are apparent from the specification and drawing which follow.

SUMMARY OF THE INVENTION

A special advantage of this invention lies in the fact that to manufacture fluid-filled plastic bodies it provides first of all that the mold cavity in the mold is completely filled with pressurized flowable plastic melt and does not provide that the melted center of such a plastic body be expelled by means of a fluid that is also pressurized until the surface of the plastic body that rests against the mold has already cooled so that, except for eventually provided inlet or outlet openings or their subsequent seals, this surface is produced repeatably without any faults from the start.

Another significant advantage of the invention lies in the fact it does not rule out any point of the mold cavity for the attachment of one or more pairs of nozzles to blow in the fluid and of outlets, connected to side cavities, for the fluid so that with any shape of plastic body regardless of geometrical complexity. Each side cavity is constructed so that after filling a side cavity with a part of the melted center of a plastic body and after the cooling and solidification of this plastic melt, the side cavity can be cleared of this solidified plastic material, or the expelled melted plastic can be used again for the next cycle (in the case of using the injection unit, the injection nozzle and the runner as a side cavity, as discussed below). Each pair of nozzles comprises a fluid blowing nozzle and an associated fluid outlet which can be constructed into a side cavity in order to blow out areas of the body having larger cross sections with fluid. In this process it can also be advantageous for a single nozzle with several outlet openings or even a single outlet opening with several nozzles to interact in pairs.

Another advantage of the invention lies in the fact that at least in special cases it also permits the use of the interior of the configuration(s) of a runner, a nozzle to inject the plastic melt and an associated injection unit as an appropriate side cavity to receive the blown out fluid center of the plastic body when the piston or the screw which works like a piston and belongs to the injection unit is withdrawn in time. In this process the expulsion can be conducted in an advantageous manner such that the portion of the expelled melted center seals every gate opening in such a manner that the wall thickness of the plastic body is not reduced. The remainder of the expelled melted center can be used in the next cycle.

In addition, it has also proven to be advantageous within the scope of the invention that, instead of or in addition to the use of the interior of one or more configurations comprising a runner, a nozzle to inject plastic melt and an associated injection unit as side cavity(ies), the interior of one cavity or several cavities arranged outside the mold cavity in the mold but connected to the mold cavity is used as an appropriate side cavity or cavities, wherein each of these connections is equipped with means to arbitrarily open and close these connections. In this manner the flexibility with respect to the aforementioned possibilities of arbitrarily adapting pairs of fluid blowing nozzles and fluid outlet openings in the mold cavity is significantly facilitated and at the same time care is taken that with simple and readily controllable means the surface of the plastic body can be built up, its melted center can be blown out and the terminating plug-like outlet opening(s) can be sealed with the remainder of the melted center.

The embodiments and the manner in which the subject matter of the invention functions are explained in detail with respect to the following drawings and detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of an injection molding machine, which is illustrated schematically during a complete filling of the mold cavity with flowable plastic melt;

FIG. 2 is a sectional view of the injection molding machine of FIG. 1 following cooling of the surface of the plastic body and during the expulsion of the melted center of the plastic body into a side cavity, formed by the interior of the runner, the nozzle and the injection unit;

FIG. 3 is a sectional view taken along line A—A of FIG. 2;

FIG. 4 is a sectional view of an injection molding machine of the invention shown schematically in which the fluid expels the melted center of the plastic body by means of a nozzle which is arranged concentrically in a nozzle to inject the plastic melt into separate, side cavities that are connected to the mold cavity;

FIG. 5 is a sectional view of a schematically illustrated injection molding machine of the invention in which the fluid has expelled the melted center of the plastic body by means of a single nozzle to inject the fluid into several separate, side cavities connected to the mold cavity; and

FIG. 6 is a sectional view of a schematically illustrated injection molding machine of the invention in which the fluid will expel the melted center of the plastic body by means of several pairs of elements, each pair comprising a nozzle to inject the fluid and an associated side cavity comprising several defined subregions of the plastic body.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a schematic drawing of an injection molding machine of the invention with an injection unit 1 (which is only shown as a fragment) in which an extruder screw 2 is provided to generate significant changes in pressure by a piston-like motion in the axial direction in addition to rotational motion. A nozzle 3 is provided to inject a flowable plastic melt 4. A multi-part mold 5 is also provided which in the illustrated case has two parts and has a runner 6 and a mold cavity 7 defined by the mold walls. In addition, the mold 5 is equipped with additional nozzles 8, 9 to inject a fluid into the mold cavity 7 which is completely filled beforehand with free-flowing plastic melt 4. These nozzles 8, 9 can be connected in the conventional manner either stationarily to a part of the tool or can be moved with respect to the part of the tool and in this embodiment are located a maximum distance from plastic melt nozzle 3.

FIG. 1 shows the injection molding machine in a stage in which the mold cavity 7 has not yet been completely filled with flowable plastic melt 4, a state which is indicated by the arrow marking the direction of the axial motion of the extruder screw 2. The nozzles 8, 9 which inject a fluid, for example compressed air, compressed nitrogen, or a pressurized suitable liquid, are not yet enveloped by the plastic melt 4. In the nozzles a fluid pressure, which just compensates for the pressure in the mold cavity 7 in the region of the nozzle openings 10, 11, is maintained in this stage.

FIG. 2 shows the injection molding machine of FIG. 1 at a later point in an injection molding cycle in which the mold cavity 7 had already been completely filled with flowable plastic melt 4 and the surface 12 of the plastic melt 4 resting against the walls of the mold cavity 7 has already set after cooling. At this point in time, on the one hand, a pressurized fluid 13 is injected through the nozzles 8, 9 into the flowable plastic melt 4 which has not set yet, i.e., in the melted center of the resulting plastic body, as indicated with the arrows under nozzles 8, 9. On the other hand, at the same time the extruder screw 2 is pulled away from the mold 5 as indicated by the arrow to increase an effective volume so that the interior of the runner 6, nozzle 3 and injection unit 1 forms a side cavity 14, which lies outside the mold cavity 7 but is connected to it, to receive the expelled free-flowing plastic melt 4. Each side cavity is constructed so that after filling a side cavity with a part of a melted center of a plastic body and after cooling and solidification of this plastic melt, the side cavity can be cleared of this solidified plastic material, or the expelled melted plastic can be used again for the next cycle (in the case of using the injection unit, the injection nozzle and the runner as a side cavity). Thus, the injection and expelling of the plastic melt occurs in substantially opposite directions in this embodiment.

The injection of the fluid 13 is not terminated until a portion of the plastic melt 4 interior to be expelled forms a plug in front of the runner 6 having the same wall thickness as the cooled surface 12. The plug supplements the cooled surface 12 which is already present in its vicinity within the mold cavity 7 to form a plastic body with a smooth and continuous outer surface without any reduction in wall thickness. The runner 6 can have a cross sectional area which is adapted for the dual function of a gate and an expulsion opening and accordingly may be larger than a conventional runner which only functions as a gate. After the final setting of the plastic body that is produced and prior to opening the mold, the pressure between the fluid-filled interior of the plastic body and the atmosphere can be balanced, for example, by means of one or both of the nozzles 8, 9. The remainder of the expelled plastic melt which does not form the plug is available for the next molding cycle.

FIG. 3 shows a sectional view taken along line A—A of FIG. 2, which assumes that the plastic body to be produced is a plate-like structure with reinforcing ribs, wherein the ribs are designed as hollow ribs. In accordance with the invention, it does not matter at this point whether the body has a rectangular shape with parallel running reinforcing ribs or a round or oval shape with radially running ribs. In particular, it should also be recognized here, in addition to FIG. 2, that in the case of complicated geometric shapes there exists the possibility of being able to define very accurately by means of the process and apparatus of the invention selected regions of a plastic body that can be produced in order to fill it with a pressurized fluid.

FIG. 4 shows another embodiment of an injection molding machine of the invention in a stage corresponding to that of FIG. 2 in which the flowable plastic melt 4 and the pressurized fluid 13 are injected one after another by means of a coaxial nozzle 15 having an inner nozzle 16 having a circular cross section to inject the pressurized fluid 13 and an outer annular nozzle 17 to inject the free-flowing plastic melt 4 into the mold cavity 7. Following the injection of the flowable plastic melt 4, the extruder screw 2 remains inoperative in its foremost position; the still flowable plastic melt 4 of the melted center of the plastic body is expelled into the demoldable side cavities 18, 19, which are arranged outside the mold cavity 7 and connected thereto and whose connections to the mold cavity 7 can be opened and closed by means of stuffers 20, 21 that can be actuated between open and closed positions. The side cavities 18, 19 are located at a maximum distance from coaxial nozzle 15 in accordance with requirements imposed on the shape of the resulting plastic body. Thus, the injection and expulsion of the plastic melt occurs in substantially the same direction. Following the expulsion of the still flowable plastic melt 4, the side cavities 18, 19 can be closed in time and in such a manner that the rest of the plastic melt forms a plug which aligns with the set surface 12 of the plastic body over the stuffers 20, 21 and whose height corresponds to at least the wall thickness of the already formed set surface 12 of the plastic body.

FIG. 5 shows another embodiment of an injection molding machine of the invention, which differs significantly from the above embodiments in that the still flowable plastic melt 4 is expelled with a single nozzle

22 separated from the plastic injecting nozzle 3. Nozzle 22 is aligned with plastic melt nozzle 3 to inject pressurized fluid in the horizontal direction of the plastic melt and is located at an opposite mold wall from nozzle 3. Nozzle 22 injects the pressurized fluid 13 into several side cavities 18, 19 located at a maximum distance from the oppositely arranged nozzles in accordance with the requirements imposed on the shape of the plastic body. In this figure a stage of an injection molding cycle is shown in which the expulsion of the still flowable plastic melt 4 from the melted center of the plastic body has just terminated. The stuffers 20, 21 are moved into a closing position that aligns with the surface of the mold cavity 7. With the remainder of the plastic melt 4, a plug, whose height corresponds to the wall thickness of the set surface 12 of the plastic body that envelops the plug, is produced above each stuffer 20, 21.

In contrast, FIG. 6 shows an embodiment which uses several pairs of nozzles 8, 9 to inject the pressurized fluid 13 and uses associated side cavities 18, 19 to provide only individual regions of a plastic body, for example interrupted reinforcing ribs at a plate-shaped structure, in a selected manner with an inner filling of pressurized fluid 13. The nozzles 8, 9 are located near nozzle 3 and direct the pressurized fluid toward associated side cavities 18, 19 located at a maximum distance from the plastic melt nozzle 3 in accordance with geometric considerations of the desired plastic body. The injection molding machine is shown in a stage of an injection molding cycle in which the setting of the surface 12 of the plastic body has advanced to such a degree that the still flowable plastic melt 4 is about to be directly expelled into the side cavities 18, 19. The stuffers 20, 21 are still positioned in such a manner in the mold cavity 7 so that they extend into the mold, are enclosed by already set material of the surface 12 and, upon release of the connections from the mold cavity 7 to the side cavities 18, 19, produce defined openings in the set surface 12. The pressure of the fluid in the nozzles 8, 9 compensates just the pressure in the mold cavity 7 in front of the nozzle openings. Following the end of the expulsion phase and the complete cooling of the fluid-filled plastic body and prior to the opening of the mold 5, here, as in all of the preceding cases, the pressure between the fluid-filled interior of the plastic body and the atmosphere can be balanced, for example, via the nozzles 8, 9 to inject the pressurized fluid and, if desired, a material exchange with the atmosphere effected.

In the preceding embodiments, pressurized fluid nozzles 8, 9 and 22 may be designed driven in order to advance into and retract out of the mold cavity with respect to a cavity wall and therefore be positionable to effect proper formation of plastic body. By retracting the fluid nozzle out of mold cavity 7, a direct channel to the atmosphere is formed to equalize pressure. This pressure equalization can also be accomplished by means of a suitable change-over valve of conventional type located in the supply line to one of the pressurized fluid nozzles.

Many modifications and improvements will be apparent to one skilled in the art without departing from the scope of the present invention as defined in the following claims.

I claim:

1. An injection molding device having a mold cavity which maintains a constant mold volume throughout a molding process and is defined by mold cavity walls comprised of separable walls, the device comprising:

means for injecting pressurized flowable plastic melt into the mold cavity to completely fill the mold cavity with flowable plastic melt;

means for injecting pressurized gas into an interior of the plastic melt after both (1) the mold cavity has been completely filled with plastic melt, and (2) a part of the plastic melt has cooled along the walls of the mold cavity to form a set surface having a wall thickness;

a first side cavity arranged outside of the mold cavity and in communication with the mold cavity to receive flowable plastic melt expelled by the injected pressurized gas;

means for opening the communication between said first side cavity and the mold cavity to enable flowable plastic melt from said interior to be blown out of the interior and into said side cavity; and

means for closing the communication between said first side cavity and the mold cavity to separate plastic melt in said side cavity from plastic melt remaining in said mold cavity, wherein said means for closing has a surface which lies flush with the mold cavity walls when said means for closing is in a closed state, said means for closing interrupting the communication such that a terminating outlet opening in the set surface is sealed with the flowable plastic melt in said interior to form a plastic body with a smooth and continuous outer surface and a wall thickness, where the outlet opening existed, which corresponds to the wall thickness of the set surface.

2. The device according to claim 1, wherein said means for injecting said pressurized flowable plastic melt comprises a nozzle, an injection unit, and an associated runner located between the nozzle and the mold cavity.

3. The device according to claim 2, further comprising a second side cavity including an interior portion of the nozzle, an interior portion of the injection unit, and the associated runner.

4. The device according to claim 3, wherein said plastic melt injecting means further comprises an extruder screw of the injection unit which moves in an extrusion direction and in a withdraw direction and wherein said second side cavity further comprises a space formed by the runner and the extruder screw when the screw has moved in the withdraw direction.

5. The device according to claim 1, wherein said plastic melt injecting means and said pressurized gas injecting means comprise concentrically arranged plastic melt and pressurized gas nozzles and the device further comprises at least one expulsion opening in one of the movable walls for communication between the mold cavity and said at least one side cavity, the at least one expulsion opening being located at a maximum distance from the concentrically arranged nozzles.

6. The device according to claim 1, wherein said plastic melt injecting means comprises a plastic melt nozzle and said pressurized gas injecting means comprises a pressurized gas nozzle located opposite the plastic melt nozzle to inject gas in the direction of the injection of the plastic melt, the device further comprising at least one expulsion opening in one of the separable walls for communication between the mold cavity and said at least one side cavity, the at least one expulsion opening being located at a maximum distance from the pressurized gas nozzle.

7. The device according to claim 1, wherein said plastic melt injecting means comprises a plastic melt nozzle, and said pressurized gas injecting means comprises a pressurized gas nozzle arranged at a maximum distance from the plastic melt nozzle.

8. The device according to claim 1, wherein said pressurized gas injecting means comprises a nozzle in communication with the mold cavity, the gas nozzle being advanceable and retractable from a cavity wall into and out of the mold cavity, wherein a connection between the fluid-filled interior of the plastic body and the atmosphere is produced by a direct channel to the atmosphere through said gas nozzle when the gas nozzle is moved out of the mold cavity.

9. The device according to claim 1, wherein said plastic injecting means comprises a plastic melt nozzle which injects plastic melt in a first direction, and said pressurized gas injecting means comprises at least two pressurized gas nozzles which inject pressurized gas in a direction which is substantially perpendicular to the first direction toward said at least one side cavity and another side cavity, respectively.

10. The device according to claim 3, further comprising means for opening and closing a communication between at least one other side cavity and the mold cavity.

11. The device according to claim 1, wherein said pressurized gas injecting means comprises a nozzle in communication with the mold cavity and wherein a connection between the fluid-filled interior of the plastic body and the atmosphere is produced by a changeover valve in a supply line for said pressurized gas injecting means which forms a communication to the atmosphere.

12. An injection molding device having a mold cavity which maintains a constant volume throughout a molding process and is defined by mold cavity walls comprised of separable walls, the device comprising:

means for injecting pressurized flowable plastic melt into the mold cavity to completely fill the mold cavity with flowable plastic melt, said means for injecting said pressurized flowable plastic melt comprising a nozzle, an associated runner located between the nozzle and the mold cavity, and an injection unit,

said injection unit comprising an interior portion and an extruder screw, said extruder screw being movable in an injection direction during injection of flowable plastic melt, and in a withdraw direction;

means for injecting pressurized gas into an interior of the plastic melt after both (1) the mold cavity has been completely filled with plastic melt, and (2) a part of the plastic melt has cooled along the walls of the mold cavity to form a set surface having a wall thickness, said means for injecting pressurized gas being operably disposed within said interior of the plastic melt formed by the cooled portion along the walls;

a first side cavity arranged outside of the mold cavity and in communication with the mold cavity to receive flowable plastic melt expelled by the injected pressurized gas, said first side cavity comprising an interior portion of said nozzle, an interior portion of said injection unit, and said associated runner;

means to move said extruder in said withdraw direction during expulsion of the flowable plastic melt to enable said flowable plastic melt from said interior to be forced into said first side cavity by the injected pressurized gas.

13. The device according to claim 12, wherein said plastic melt injecting means comprises a plastic melt nozzle, and said pressurized gas injecting means comprises a pressurized gas nozzle at a maximum distance from the plastic melt nozzle.

14. The device according to claim 12, wherein said pressurized gas injecting means comprises a nozzle in communication with the mold cavity, the gas nozzle being advanceable and retractable from a cavity wall into and out of the mold cavity, wherein a connection between the fluid-filled interior of the plastic body and the atmosphere is produced by a direct channel to the atmosphere through said gas nozzle when the gas nozzle is moved out of the mold cavity.

15. The device according to claim 12, wherein said pressurized gas injecting means comprises a nozzle in communication with the mold cavity and wherein a connection between the fluid-filled interior of the plastic body and the atmosphere is produced by a changeover valve in a supply line for said pressurized gas injecting means which forms a communication to the atmosphere.

16. An injection molding device having a mold cavity which maintains a constant volume throughout a molding process and is defined by separable walls, the device comprising:

means for injecting pressurized flowable plastic melt into the mold cavity to completely fill the mold cavity with flowable plastic melt;

means for injecting pressurized gas into an interior of the plastic melt after both (1) the mold cavity has been completely filled with plastic melt, and (2) a part of the plastic melt has cooled along the walls of the mold cavity to form a set surface having a wall thickness, said means for injecting pressurized gas operably disposed within said interior of the plastic melt formed by the cooled portion along the walls;

a first side cavity arranged outside of the mold cavity and in communication with the mold cavity to receive flowable plastic melt expelled by the injected pressurized gas;

means for opening the communication between said first side cavity and the mold cavity to enable flowable plastic melt from said interior to be blown out of the interior and into said first side cavity;

means for closing the communication between said first side cavity and the mold cavity to separate plastic melt in said first side cavity from plastic melt remaining in said mold cavity, wherein said means for closing has a surface which lies flush with the mold cavity walls when said means for closing is in a closed state, said means for closing interrupting the communication such that a terminating outlet opening in the set surface is sealed with the flowable plastic melt in said interior to form a plastic body with a smooth and continuous outer surface and a wall thickness, where the outlet opening existed, which corresponds to the wall thickness of the set surface; and

means for advancing and retracting said means for injecting pressurized gas, into and out of the mold cavity.

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US005246646A

United States Patent [19]

Baxi

[11] **Patent Number: 5,246,646**

[45] **Date of Patent: Sep. 21, 1993**

[54] **INJECTION MOLDING METHOD**

[75] Inventor: **Indra R. Baxi**, Troy, Mich.

[73] Assignee: **Dean Lamer**, Madison Heights, Mich.

[21] Appl. No.: **685,519**

[22] Filed: **Apr. 15, 1991**

Related U.S. Application Data

[62] Division of Ser. No. 266,476, Nov. 2, 1988, Pat. No. 5,015,166.

[51] **Int. Cl.**[5] **B29C 45/76**; B29D 22/00

[52] **U.S. Cl.** **264/40.3**; 264/328.8; 264/328.12; 264/328.13; 264/572

[58] **Field of Search** 264/40.3, 85, 328.8, 264/328.12, 328.13, 500, 572

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,106,887 8/1978 Yasuike et al. 425/549

FOREIGN PATENT DOCUMENTS

54-123173 9/1979 Japan 264/40.3

57-14968 3/1982 Japan 264/572

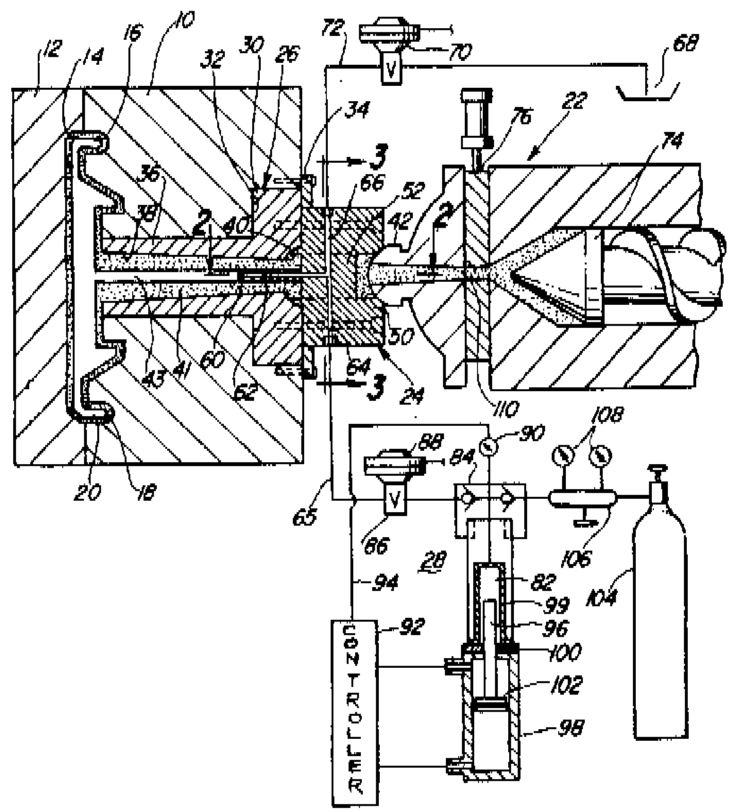
Primary Examiner—Leo B. Tentoni

Attorney, Agent, or Firm—Dykema Gossett

[57] **ABSTRACT**

A method and apparatus for making a plastic injection molded part with a smooth surface or skin and a hollow core wherein thermoplastic material is injected as a molten stream into the mold cavity through a sprue bushing fixed in the mold. Simultaneously, an unmeasured quantity of inert gas is introduced through an adapter into the molten stream at the sprue bushing substantially coaxially with the melt stream and at a pressure sufficient to penetrate the thermoplastic material to form a gas cavity in the molten material in the mold. For retrofitting an existing mold, an adapter can be added to the exisiting sprue bushing. During plastic injection and cooling in the mold the gas is maintained at a high pressure, preset, constant and adequate to maintain the plastic against the mold surface until it is self-supporting. The gas is exhausted from the mold, back through the sprue bushing and adapter, before the mold is opened. Adequate preset high pressure is maintained at the gas supply by a large cylinder having a positive displacement member therein that is controlled by a pressure sensor in the gas pressure line to the mold to maintain preset adequate gas pressure within the cavity.

3 Claims, 1 Drawing Sheet



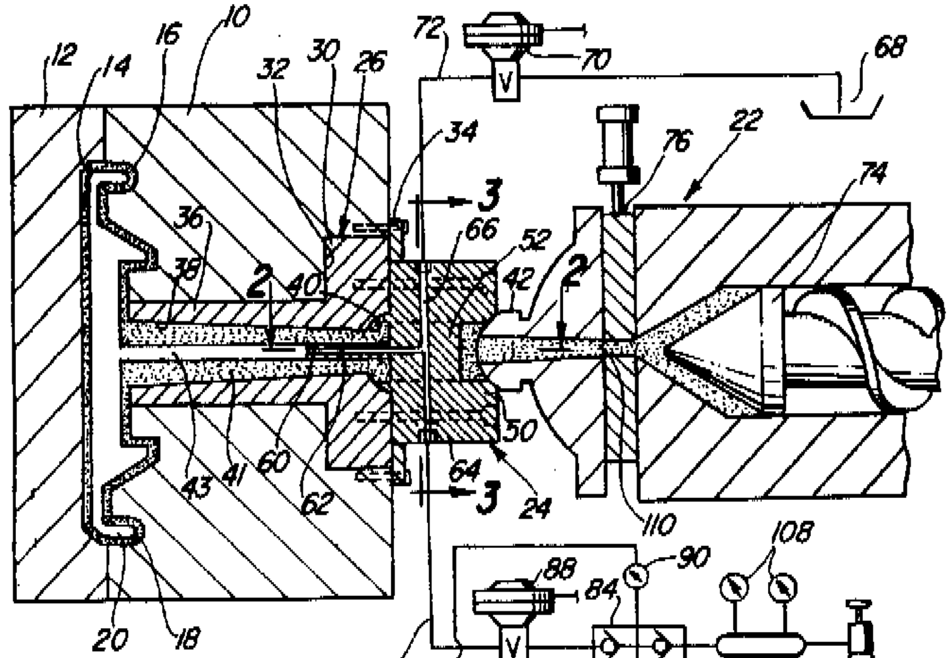
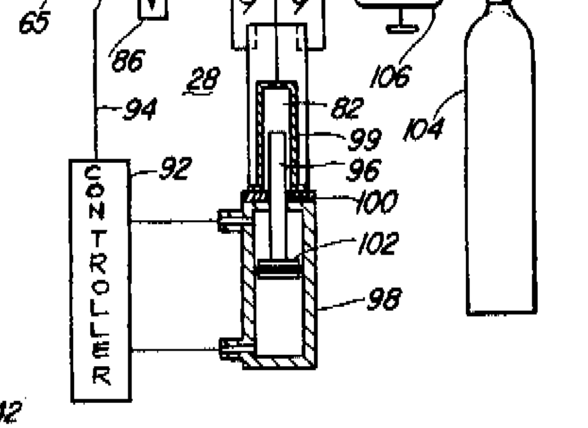



Fig-1

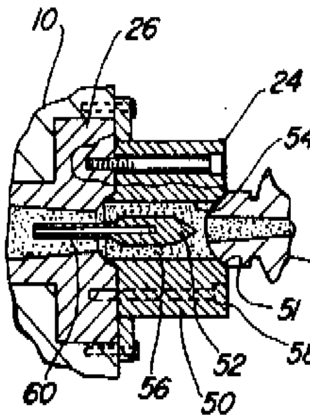


Fig-2

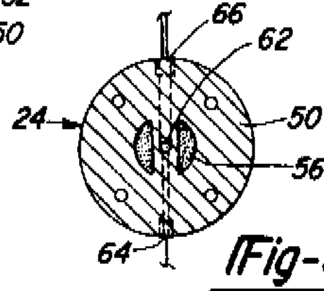


Fig-3

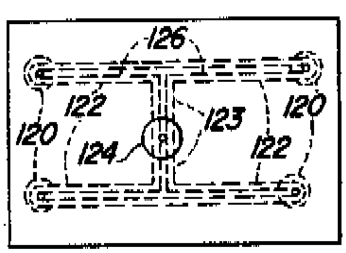


Fig-4

INJECTION MOLDING METHOD

This is a divisional of copending application Ser. No. 07/266,476 filed on Nov. 2, 1988, now U.S. Pat. No. 5,015,166.

BACKGROUND OF INVENTION

1. Field of Invention

The present invention relates to apparatus and methods for making injection molded thermoplastic parts, particularly gas assisted injection molding of parts having a smooth outer skin and a hollow core.

2. Prior Art

Various injection molding techniques have heretofore been proposed to use less material and achieve weight and cost reduction while maintaining structural properties and providing a smooth outer surface or skin that does not require sanding or other finishing. Blowing agents, including gas, can be used to provide a porous, foamed or cellular core and in some cases a hollow core. When gas is used to form a hollow core, the gas can be injected into the plastic melt stream at the nozzle or directly into the mold, preferably in a controlled manner to achieve the desired core structure.

U.S. Hendry Pat. No. 4,474,717 discloses several apparatus and methods wherein gas is injected into the mold by means of a gas injection probe. A small amount of plastic is first injected into the mold to encapsulate a gas injection probe and thereafter gas is injected through the probe while injection of the plastic continues to form the desired core structure. At the end of the molding operation gas pressure in the mold is relieved by exhausting the mold cavity through the probe which acts as a decompression valve. A similar gas injection—decompression valve in the mold is also disclosed in U.S. Sayer Pat. No. 4,740,150. In both the Hendry and Sayer patents the gas injection probe or nozzle is shown mounted in that half of the mold opposite the mold half through which the plastic is injected, as from a reciprocating screw injection molding machine. Although injecting and/or exhausting gas into the mold cavity in the manner taught by the Hendry and Sayer patents may well provide the desired core structure, modification of each mold is required to accommodate the gas injection nozzle or probe. This may be expensive and involves care in selecting the location of the gas injection nozzle, particularly in multiple cavity molds and in retrofitting existing molds.

Other gas injection techniques have also been proposed wherein the gas or a foaming agent is introduced into the melt stream prior to the mold cavity at the nozzle of the plastic injector as shown in U.S. Friedrich Pat. No. 4,101,617 or into the cavity after plastic injection by a special manifold as shown U.S. Olabisi Pat. No. 4,136,220. Again, modification of the nozzle or manifold may also be expensive and require changing the nozzle or manifold for different applications depending on the part being molded by that machine

Other gas injection locations have also been suggested U.S. Pat. No. 4,498,860 (Gahan) discloses an inclined retractable piston mounted in a mold half that can be extended to close off a reverse taper sprue passageway and thereby cut off the sprue. A small pipe coaxial with the piston is disclosed for injecting gas into the plastic material to flow with the plastic through the mold space. Here again rather elaborate modification of the mold is required to accommodate the holder for the sprue cut-off piston. The inclined orientation of the gas injection tube would undoubtedly cause uneven distribution of the gas in the plastic entering the mold and otherwise detract from effective gas injection.

Whether gas is injected into the mold as in the Sayer and Hendry patents or into the melt stream before the mold as in the Friedrich patent, the gas injection should be compatible with different gas injection systems to precisely control injection of the gas This may require further modification of the nozzle or the mold which in turn adds to expense, particularly where the gas injection system is installed as a retrofit for an existing mold to make a previously solid part into a hollow core part.

In retrofitting existing injection molding equipment and molds, as well as with new equipment, various techniques have been proposed to more precisely control the gas injection and achieve the desired core structure repeatably over long production runs. One approach is described in general terms in the aforementioned U.S. Sayer Pat. No. 4,740,150 and in British Patent Specification No. 2,139,548 referred to therein, wherein a preselected or measured volume of pressurized gas is injected into the mold during each molding cycle.

A process using what may be generally termed as preset pressure has also been proposed in Baxi European application, Application No. 87304002.6, filed May 5, 1987, published Dec. 23, 1987, Publication No. 0250080A2, Bulletin 87/52. With this process, as contrasted to the preset volume technique, the quantity of gas that is introduced into the mold is not directly measured but only the pressure of the gas is controlled. A gas supply source is provided along with gas pressurization means for pressurizing the gas to a preset pressure which is at least as great as the pressure at which the molten plastic material is introduced into the mold. A storage chamber is provided for storing gas at the preset pressure so that the gas is immediately available for use when injection of the plastic material is initiated. Gas pressure maintains the plastic against the surfaces of the mold cavity as the plastic cools and until the plastic can sustain the form dictated by the mold to provide an essentially hollow part. As set forth in European Patent Publication 0,250,080, prior to injection of the plastic, a high pressure gas storage tank is fully charged at the pressure preset for that molding operation Just after plastic injection is initiated, high pressure gas from the storage tank is injected into the plastic melt steam by a feed chamber in the nozzle. The high pressure tank is charged and recharged by a pump controlled by a pressure switch so that sufficient gas in the high pressure tank is always available at the preset pressure. Asahi Dow Ltd. Japanese Application No. 120318/1973, filed Oct. 25, 1973, published Mar. 27, 1982, Publication No. 14968/1982, shows a similar arrangement for injecting gas via a high pressure piston or ram and injection inlet at the nozzle.

Although the preset volume and preset pressure processes described in the prior art may well provide improved results as contrasted to gas injection that is not as precisely controlled, both processes have disadvantages that detract from precise and repeatable control of the gas injection. In the constant volume process it is difficult to maintain repeatability over many molding cycles due to variations inherent with constant volume cylinder and piston arrangements caused by wear and other variations with time and extended use. In the preset pressure method using a high pressure storage tank that must be replenished, the preset pressure can and will vary during an injection cycle as gas is released from the tank and replenished by the pump.

Accordingly it is desirable to provide improved methods and apparatus for injection molding of hollow parts which overcome the foregoing and other difficulties while providing better and more advantageous overall results.

BRIEF SUMMARY OF THE INVENTION

In accordance with the present invention new and improved methods and apparatus are provided for producing a hollow injection molded part.

More particularly, in accordance with the present invention there is provided a method and apparatus for making a plastic injection molded part with a smooth surface or skin and a hollow core wherein thermoplastic material and gas are injected into the mold cavity. The gas is maintained at a high pressure, preset, constant and adequate to maintain the plastic against the mold surface until it cools sufficiently to be self-supporting. The gas is exhausted from the mold before the mold is opened. Adequate preset high pressure is maintained at the gas supply by a large cylinder having a positive displacement member therein that is controlled by a pressure sensor in the gas pressure line to the mold to maintain preset adequate gas pressure within the cavity during injection and cooling.

In the preferred embodiment, the plastic is injected as a molten stream into the mold cavity through a sprue bushing fixed in the mold. Simultaneously, an unmeasured quantity of inert gas is introduced through an adapter into the molten stream at the sprue bushing substantially coaxially with the melt stream and at a pressure sufficient to penetrate the thermoplastic material to form a gas cavity in the molten material in the mold. For retrofitting an existing mold, the gas injection adapter can be mounted on the existing sprue bushing.

The principal object of the present invention is to overcome, or at least minimize, the disadvantages of prior art gas assisted injection molding and provide methods and apparatus for gas assisted injection molding that produce a superior plastic part having a hollow cavity therein and a smooth outer surface and reduced sink marks and part warp and which are effective, efficient and economical and provide greater flexibility using conventional injection molding equipment.

BRIEF DESCRIPTION OF THE DRAWINGS

The above objects and other features and advantages of the present invention will be apparent from the following detailed description, appended claims and accompanying drawings in which:

FIG. 1 is a fragmentary elevational plan view, partly in cross section, schematically illustrating a mold with a sprue bushing, a sprue bushing adaptor, a reciprocating screw injection molding machine and a pressurized gas supply system;

FIG. 2 is an enlarged fragmentary sectional view taken on lines 2—2 of FIG. 1;

FIG. 3 is an enlarged fragmentary sectional view taken on lines 3—3 of FIG. 1; and

FIG. 4 schematically illustrates a further embodiment of the present invention applied to a mold having four openings in the mold cavity.

It will be understood that the drawings described above merely illustrate a preferred embodiment of the present invention and that other embodiments are contemplated within the scope of the claims hereinafter set forth.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring generally to the molding apparatus shown in FIG. 1, a stationary mold half 10 and a moveable mold half 12 are shown in their closed position defining a mold cavity 14 for molding a plastic part 16 having an outer shell 18 forming a hollow core 20. Plastic is injected into cavity 14 through a sprue bushing adapter 24, and a sprue bushing 26. Gas from a supply system designated generally at 28 is introduced into the melt stream at sprue passage 38 via adapter 24. In the embodiment being described adapter 24 has been retrofitted to an existing mold already having a conventional sprue bushing 26. Existing molds are retrofitted when it is desired to convert molding of a solid part to molding the same part with a hollow core such as core 20.

Referring to FIGS. 1-3 in greater detail bushing 26 has a flanged head 30 mounted in a recess 32 in mold half 10 by a press fit and by a retaining plate 34 bolted on mold half 10. A bushing sleeve 36 integral with head 30 extends through mold half 10 and has an outwardly tapered sprue passage 38 opening into cavity 14 at the left end as viewed in FIG. 1. Sleeve 36 may also be press fitted in mold half 10. Sprue passage 38 opens at its narrow end in head 30 at a hemispherical recess 40 that provides a seat for a nozzle 42 of injection molding machine 22 prior to retrofit. At the completion of an injection, passage 38 contains a sprue in the area generally designated at 41 and the sprue will have a gas channel 43 therethrough.

As is generally well known sprue bushings such as bushing 26 provide inexpensive protection of the mold so that damage occurs at the bushing which can be replaced inexpensively. To this end, sprue bushing 26 typically is made of hardened steel to withstand the impact of the nozzle, both during setup and repeated injection cycling as the injection forces are applied at the interface between bushing 26 and nozzle 42.

Sprue passage 38 conventionally has a ground and highly polished finish to minimize friction with the melt and thereby minimize frictional heating of the plastic that would cause degradation and burn spots in the finished product. Repeated injection through the sprue passage 38 will, over extended use, scratch and scorch the surface due to the abrasiveness of the plastic material. This wear and surface imperfection may be pronounced with glass filled plastic, for example. A worn sprue passage, particularly at high injection speeds, also causes turbulance and frictional flow at the walls, creating undesirable pressure drops, interfering with proper filling of the mold and impairing the flow of the plastic to the mold extremities. In any event, conventional sprue bushings provide an inexpensive way to repair the damage by replacing the bushing. Although bushing 36 is illustrated as unheated, it should be understood that the present invention is equally applicable to heated sprue applications.

Sprue bushing adapter 24 comprises a steel body 50 having an integral torpedo like web 52 transverse of a through passage 54 in body 50 splitting passage 54 into two aperatures 56 at the torpedo web Body 50 is also hardened steel and has a nozzle seat 51 and at the inlet end of passsage 54. Body 50 is bolted on bushing 26 at 58 and may also be silver soldered at the interface with head 30 and recess 40 to eliminate flash. Web 52 has an integral needle-like gas injection probe or nozzle 60 extending coaxially within sprue passage 38 and having a gas passage 62 therein. Adapter 24 has opposed radial gas inlet and exhaust passages 64, 66 that extend through web 52 and communicate at their inner ends at a T connection with passage 62 in nozzle probe 60. Inlet passage 64 is connected at its outer end to gas supply system 28 via a high pressure line 65. Exhaust passage 66 is connected to a decompression baffle 68 via a solenoid operated valve 70 and line 72. Preferably exhaust passage 66 has a larger diameter, than passage 64, say twice as large, so as not to get plugged if plastic is sucked back when cavity 14 is decompressed. Although probe 60 is illustrated projecting slightly into sprue passage 38, it can be longer or shorter, depending on the specific application. In one application the probe opened generally in line with the juncture of recess 32 and sprue passage 38 and in another application extended nearly to cavity 14. In both cases, however, the passage 62 was coaxial with the sprue bushing to inject gas coaxially into the melt stream in the direction material flow.

Injection molding machine 22 has a conventional reciprocating screw 74 and cylinder operated shut-off valve 76. In FIG. 1, screw 74 is shown at the end of its stroke just prior to closing of the valve 76 with part 16 substantially fully formed.

Pressurized gas is provided to sprue bushing adapter 24 during the injection stroke via a line 65 from a high pressure chamber 82 through a check valve assembly 84 and a valve 86 operated by solenoid 88. The gas pressure in chamber 82 is monitored by a gas pressure indicator-sensor 90 that provides an electrical output signal to controller 92 via lead 94 when the gas pressure falls below a preset pressure. When gas in chamber 82 is delivered to pressure line 65 through check valve assembly 84 and valve 86, piston rod 96 is moved by an hydraulic cylinder 98 which in turn is operated by controller 92 to decrease the volume of chamber and maintain constant pressure. Rod 96 projects into chamber 82 but has no sliding seals on the chamber walls 99. Piston rod 96 extends downwardly through the walls of cylinder 98 and chamber 82 and wet metallic seals 100 to a piston 102 in cylinder 98. Low pressure gas is supplied to chamber 82 from a supply tank 104 via reducing valve 106 and check valves 84. The gas is preferably nitrogen.

Prior to the start of the molding cycle, valves 70 and 86 are closed and inert gas is stored in chamber 82 by activating controller 92 and hydraulic cylinder 98 to retract rod 96 and piston 102 down as viewed in FIG. 1. This draws relatively low pressure gas from tank 104, into the empty gas chamber 82. The gas will continue to flow into chamber 82 until the pressure in the chamber equals the pressure of the gas entering from the supply tank 104, which is set by pressure reducing valve 106 and indicated by pressure gages 108. The gas pressure in chamber 82 may be relatively low at say 150 to 250 psi. Check valve assembly 84 prevents gas from returning to tank 104. Cylinder 98 is then actuated to extend rod 96 into chamber 82, compressing the gas in chamber 82 to a desired preset high pressure, for example 2000 psi and higher, as set and indicated at pressure indicator-sensor 90. In general, the gas pressure is set to be at least greater than the plastic injection pressure at sprue bushing 26 and cavity 14. At the desired pressure required, the piston 102 will stop in response to the control signal at lead 94 and stay in the up position until such time, during the subsequent injection operation when the pressure drops below the required preset gas pressure. With chamber 82 fully charged to the desired present pressure, and the valves 70, 84, 86 closed, the molding cycle is in the start position.

To initiate the molding cycle, the molding press clamping unit (now shown) is closed, holding mold halves 10 and 12 closed under a clamping force which is in excess of the plastic melt and gas injection pressures. Under the control of the injection cycle controller (not shown) for machine 22, nozzle shut-off valve 76 is opened and screw 74 is activated to ram molten plastic 110 through nozzle 42, adapter 24, sprue bushing 26 and into the mold cavity 14. As the molten plastic enters the sprue bushing 26 past the gas injection probe 60, valve 86 is immediately opened by the cycle controller, allowing high pressure gas from chamber 82 to flow through line 65, into passages 64 and 62 where it is injected into the melt stream in the sprue passage 38. Preferably gas injection is initiated so that the outlet end of nozzle probe 50 is encapsulated with molten plastic just before the gas flow starts in a manner similar to that disclosed in the above identified U.S. Hendry Pat. No. 4,474,717. During plastic injection exhaust valve 70 remains closed

As the gas enters the melt stream in the sprue passage 38, the higher gas pressure pushes the molten plastic rapidly to mold cavity 14 and against the cavity walls forming the hollow core 20 as the plastic cools. The pressure of the gas entering the melt stream during plastic injection and maintained in cavity 20 via gas channel 43 during cooling is constant and does not vary significantly during the molding cycle. When the gas pressure in chamber 82 starts to drop, the pressure indicator-sensor 90, actuates controller 92 which moves piston 102 upward to extend rod 96 further into chamber 82 to maintain gas pressure at the preselected level in chamber 82 and core 20.

When screw 74 finishes its forward movement the gas flow will continue for a short period to pack molten plastic against the mold surfaces Valve 86 is then closed by the cycle controller. For a period of time set by the controller cycle (not shown), this gas pressure is held constant until the molten plastic shell 16 in the mold cavity 14 has cooled sufficiently to be self-supporting. The gas exhaust valve 70 is then opened by the cycle controller to decompress gas from cavity 14, back through the open gas channel 43 in sprue 41, passages 54, 66, line 72 and vent the exhausted gas to the ambient atmosphere via baffle 68. The mold can subsequently be opened and the molded part 16 removed from the mold.

During the decompression time at cavity 14 and between molding cycles, cylinder 98 retracts piston 102 and rod 98. Chamber 82 is recharged and then rod 96 is extended until the gas pressure in chamber 82 reaches the desired setting at indicator on the sensor 90. The system is then ready for a repeat cycle, with valves 86 and 70 closed.

With the arrangement described, the gas injection probe 60 opens in the sprue bushing 36 coaxial with sprue passage 38 in the same direction as the flow of the melt stream. This allows the use of a standard sprue bushing opening at the mold without altering the standard sprue bushing or opening design This is particularly important in a retrofit since the sprue bushing configuration need not change including where the sprue passage 38 opens into the cavity. Hence, variation in plastic flow parameters are not introduced from standard sprue design.

Another advantage of gas injection at the sprue bushing is the elimination of a cold slug that would be present if the gas is injected and exhausted at the nozzle. When gas is exhausted through the nozzle it cools the nozzle tip slightly causing freeze up and cold slugs.

Considering further advantages of coaxial gas injection of the sprue bushing in the direction of material flow, after the gas inlet has been encapsulated by the melt stream, as the plastic and gas injection continue, an envelope is formed which moves into the mold cavity 14 and expands into the cavity extremities, all while the envelope is sufficiently fluid to expand under the gas pressure. Once the envelope fills the cavity to form shell 18, particularly with constant pressure maintained inside the shell, the shell is packed against the wall until such time as it is self supporting. Coaxial injection of the gas into the melt stream at the sprue bushing provides uniform distribution of the gas and gas pressure forces in the melt stream and the envelope as it expands in the mold cavity. Coaxial gas injection at the sprue bushing also insures that the gas enters the melt stream where it is always viscous. Coaxial injection of the gas at the sprue bushing in the direction of flow of the melt stream also minimizes turbulance in the melt stream which could result in isolated bubbles in the final part.

Although gas injection at the sprue bushing has been described in the preferred embodiment in connection with the constant pressure gas delivery system 28, the advantages are useful with other gas delivery systems, for example of the types disclosed in the above identified prior art.

Similarly, although gas injection at the sprue bushing has been described for retrofitting an existing mold it is equally advantageous with new molds For new mold applications, inexpensive standard sprue bushings can be used and the adapter 24 fastened to the sprue bushing and preferably silver soldered at interfaces to prevent flash. Where special sprue bushings are required part of the adapter can be manufactured as an integral part of the bushing However, for retrofitting existing molds or for new mold applications the gas injection mechanism is part of the sprue bushing as contrasted to being in the nozzle or directly in the mold. Hence, no significant modification of either the mold or the injection molding machine is required. If the sprue bushing or the adapter gets worn or damaged, it can simply be removed and replaced.

Although the sprue bushing is preferred for many applications, it will be understood that for some applications the mold does not need to have a sprue bushing The adapter 24 to provide gas injection would then be mounted on the mold to convey the melt stream to the cavity so that the gas and melt stream enter the mold cavity together In such applications the part would have some portion, in the nature of a sprue, where the plastic is injected and which is either nonfunctional, part of the runner system or some other portion that is later removed from the finished parts. Hence in the broader sense, the present invention contemplates use of the adapter to inject gas into the melt stream downstream and independent of the nozzle at a sprue or sprue like portion of the part or part runners.

FIG. 4 shows a further embodiment of the present invention where the mold cavity (not shown) has four hot sprues 120 commonly known as hot drops. Each hot drop sprue 120 is connected by hot runners 122, 123 to a main sprue bushing 124 that would normally receive plastic from the nozzle of the injection molding machine. By mounting an adapter like adapter 24 at bushing 124, gas can be introduced into the melt stream for distribution to each of the four hot drop sprues 120. To even further insure even gas distribution to each of the hot drop sprues, the gas injection probe can be fashioned to branch into and extend through runners 123, 122 to each of the hot drop sprues 120 as indicated by tubes 126 shown in dotted lines in FIG. 4. The tubes 126 open in the melt stream at each hot drop sprue 120 coaxially therewith and in the direction of material flow into the mold.

The gas delivery system 28 also has advantages over the prior art delivery systems identified above. Gas delivery system 28 maintains constant pressure during injection and cooling in the mold to insure that the part is packed in full contact with the cavity wall until the part is self supporting. Constant pressure is achieved because as soon as any gas is depleted from chamber 82, rod 96 is extended, instantaneously and automatically, into the chamber 28 displacing the depleted gas and maintaining the pressure constant. This is in contrast to constant volume systems where the gas pressure drops off during injection and prior art attempts to achieve substantially constant pressure by pistons, pumps and the like.

Chamber 82, rod 96 and the stroke of piston 102 are selected so that chamber 82 contains more than enough gas for each injection and rod 96 never bottoms out on the chamber walls. Consequently, once chamber 82 is pressurized to the desired preset pressure, the pressure can be maintained constant throughout injection by displacing the gas as it is used. This is also in contrast to using a piston in a gas compression cylinder because more than sufficient pressurized gas for each injection is stored in chamber 82. Rod 96 does not require piston rings or other dry sliding seals in chamber 82. Introduction of lubricants into the gas would impair the surface finish or create unwanted surface and other bubbles in the part. Although seal 100 is wetted by hydraulic fluid in cylinder 98, the design of such metal seals to prevent hydraulic fluid from leaking into chamber 82 is well known. Since no additional heat is generated in chamber 82 by friction of moving seals, longer life and more reliable operation is achieved.

As indicated earlier, gas delivery system 28 is a high pressure system. Although the preset pressure will vary depending on the molding parameters for each application, generally gas pressures in the range of 2,000 to 7,000 psi and even higher are contemplated, the gas injection pressure is selected to be above the melt pressure where the gas is injected. Typically, general purpose polymers such as polyproplyene and polyethylene are at the lower end of the range, say 1,800 psi in the sprue bushing 26 where the gas would be injected at a slightly higher pressure in excess of 2,000 psi. With glass and mica filled nylon, ABS, and LEXAN, for example, at the upper end of the range higher melt pressures of 3,500 to 7,000 psi might be present and the gas pressure preset at indicator-sensor 90 would again be above the melt pressure

Although gas injection at sprue bushing 26 can be used with various gas delivery systems and gas delivery system 28 can be used to inject gas at locations other than the sprue bushing, the combination of gas injection at the sprue bushing using the constant gas pressure of gas delivery system 28 is preferred. The two features are particularly compatible to achieve a better molded part. The melt stream is still highly viscous at the sprue bushing and at pressures that allow gas injected at constant pressures to achieve effective coring of the molded part and smooth surfaces that do not require finishing.

It will be understood that the injection molding apparatus and method have been described hereinabove for purposes of illustration and are not intended to indicate limits and modifications of the present invention, the scope of which is defined by the following claims.

I claim:

1. A method of gas assisted injection molding of a plastic part comprising the steps of:

(1) injecting molten plastic into a mold;

(2) introducing gas into the plastic from a source of gas at a preselected pressure;

(3) monitoring the gas pressure during step (2) upstream of said mold; and

(4) using the monitored gas pressure as feedback to control the gas pressure injected into the mold during step (2) to ensure that said monitored gas pressure remains substantially constant and at the preselected gas pressure during step (2).

2. The method as recited in claim 1, wherein the gas source is a gas supply chamber and the gas pressure is controlled by controlling the volume of the gas supply chamber.

3. The method as recited in claim 2, wherein the gas supply chamber includes a piston which is moved to control the volume of the chamber in response to the monitored gas pressure.

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US005110533A

United States Patent [19]

Hendry

[11] Patent Number: 5,110,533
[45] Date of Patent: May 5, 1992

[54] METHOD FOR THE USE OF GAS ASSISTANCE IN THE MOLDING OF PLASTIC ARTICLES TO ENHANCE SURFACE QUALITY

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[73] Assignee: Milad Limited Partnership, Naples, Fla.

[21] Appl. No.: 610,386

[22] Filed: Nov. 7, 1990

[51] Int. Cl.[5] B29C 45.00; B29C 45.34; B29D 22/00

[52] U.S. Cl. 264/572; 264/328.8; 264/328.12; 264/328.13; 425/812

[58] Field of Search 264/85, 328.8, 328.12, 264/328.13, 572; 425/812

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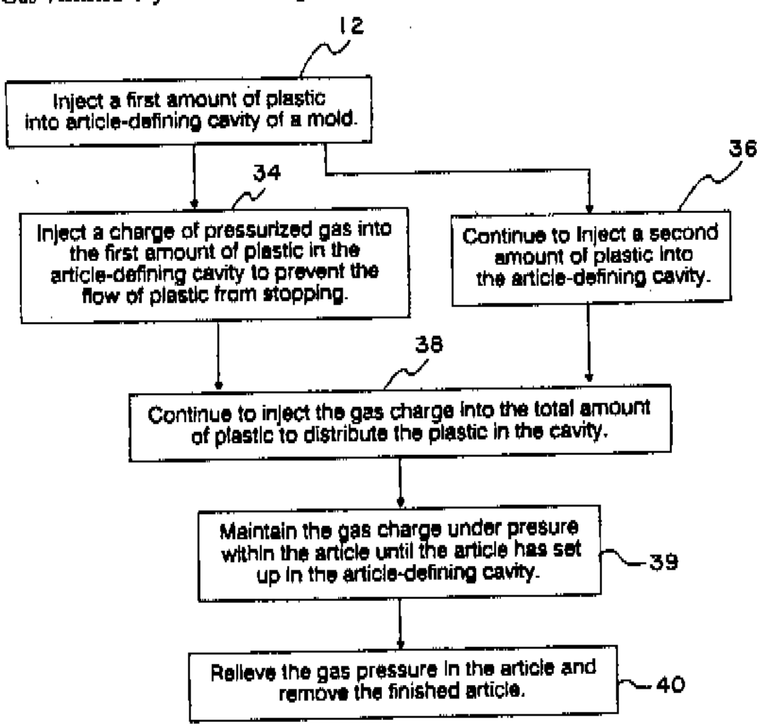
Primary Examiner—Leo B. Tentoni
Attorney, Agent, or Firm—Brooks & Kushman

[57] ABSTRACT

A method of gas-assisted injection molding in which: (1) a first amount of plastic is injected into an article-defining cavity of a mold so that it flows therein; (2) a second amount of plastic continues to be injected into the cavity simultaneous with the injection of a charge of pressurized gas wherein the pressurized gas prevents the flow of plastic in the cavity from stopping; and (3) the charge of pressurized gas continues to be injected after the second amount of plastic is injected to distribute the total amount of molten plastic resin in the cavity. The ratio for the first amount of plastic to the total amount of plastic required for the preparation of the article is in the range of 0.2 to 0.7. Also, the pressurized gas has a pressure between approximately 1000 psi and 5000 psi. These steps prevent imperfections on the exterior surface of the plastic article. The gas charge is maintained under pressure within the article until the article has set up in the article-defining cavity. Finally, the gas pressure is relieved in the article and the finished article is removed from the mold. The method is particularly useful in molding articles having a relative large cross-section.

6 Claims, 5 Drawing Sheets



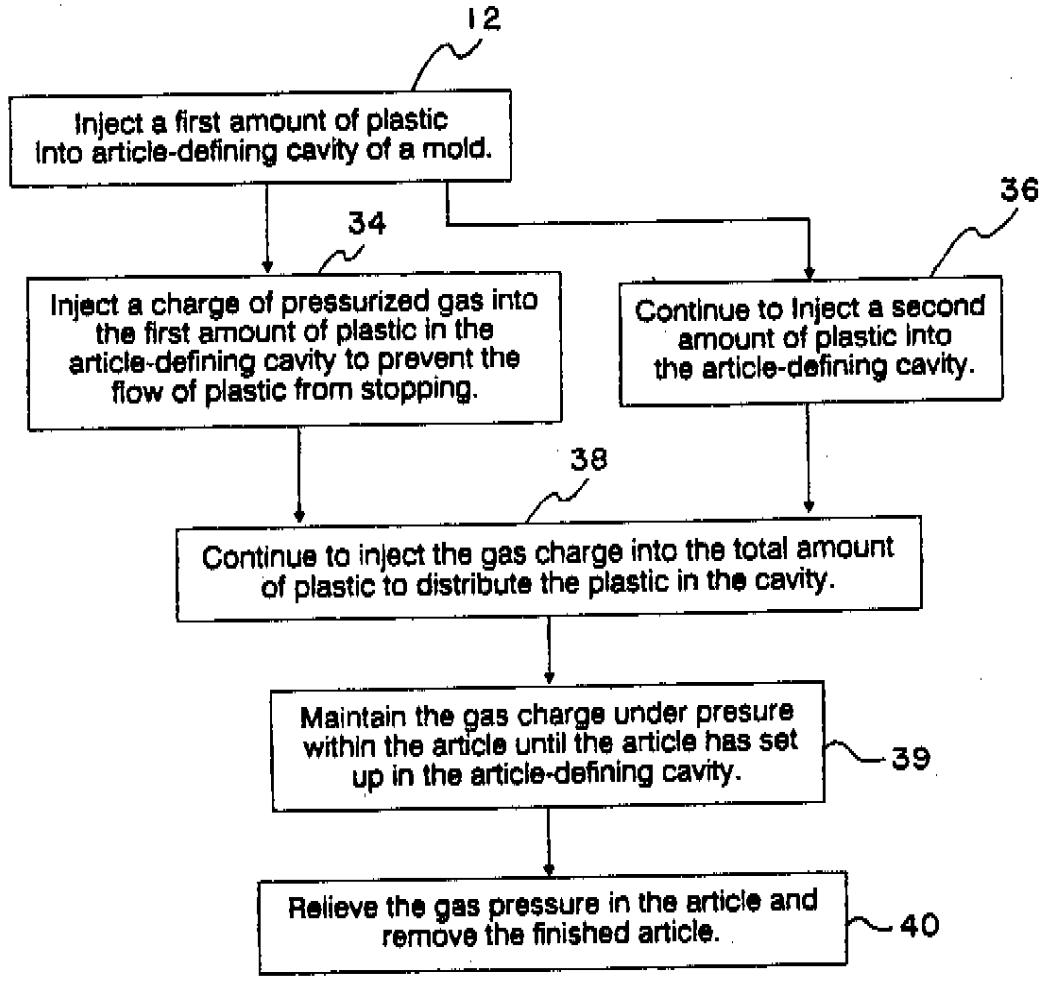

12
Inject a first amount of plastic into article-defining cavity of a mold.
34
Inject a charge of pressurized gas into the first amount of plastic in the article-defining cavity to prevent the flow of plastic from stopping.
36
Continue to inject a second amount of plastic into the article-defining cavity.
38
Continue to inject the gas charge into the total amount of plastic to distribute the plastic in the cavity.
Maintain the gas charge under presure within the article until the article has set up in the article-defining cavity.
39
Relieve the gas pressure in the article and remove the finished article.
40

FIG. 1

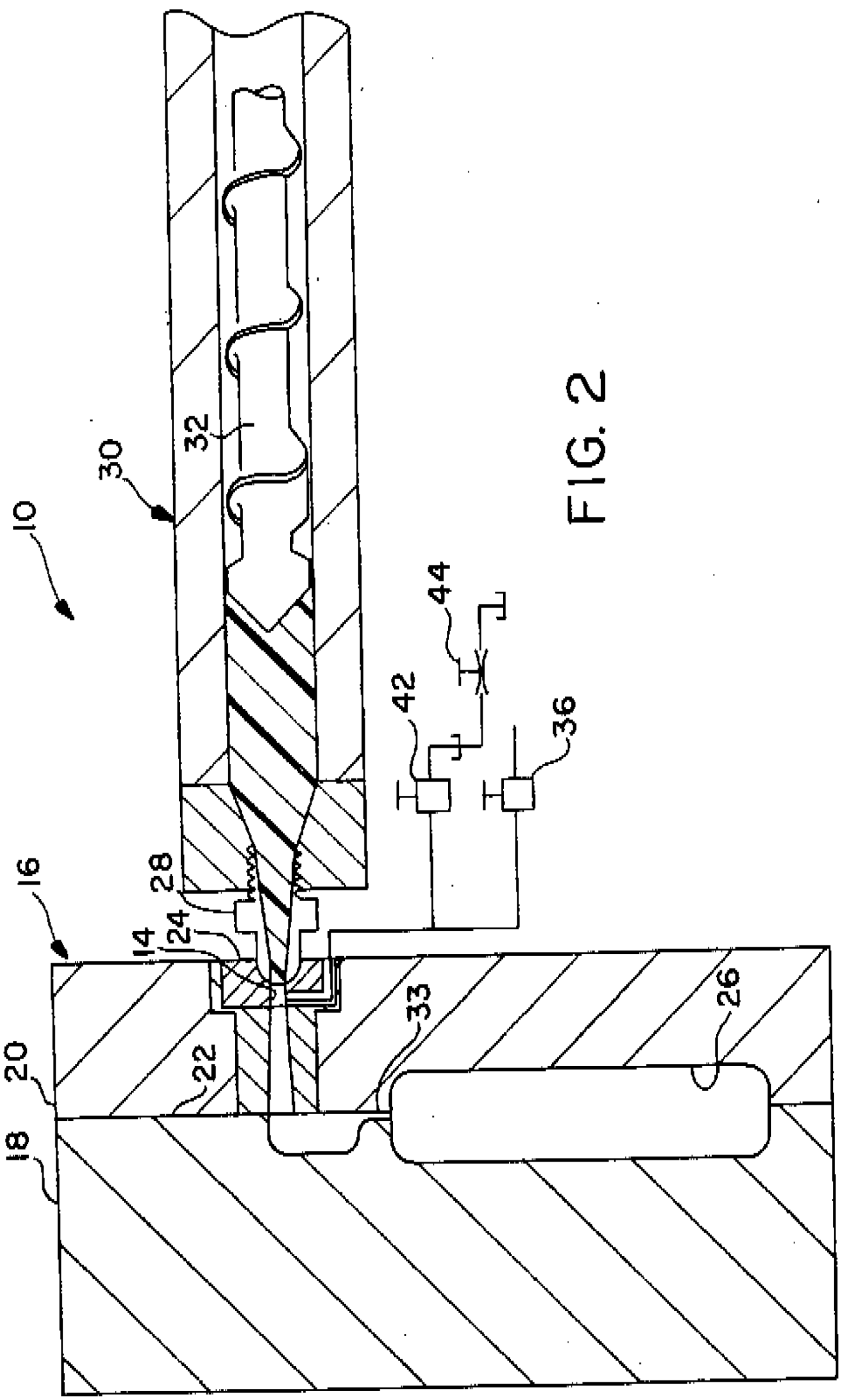


FIG. 2

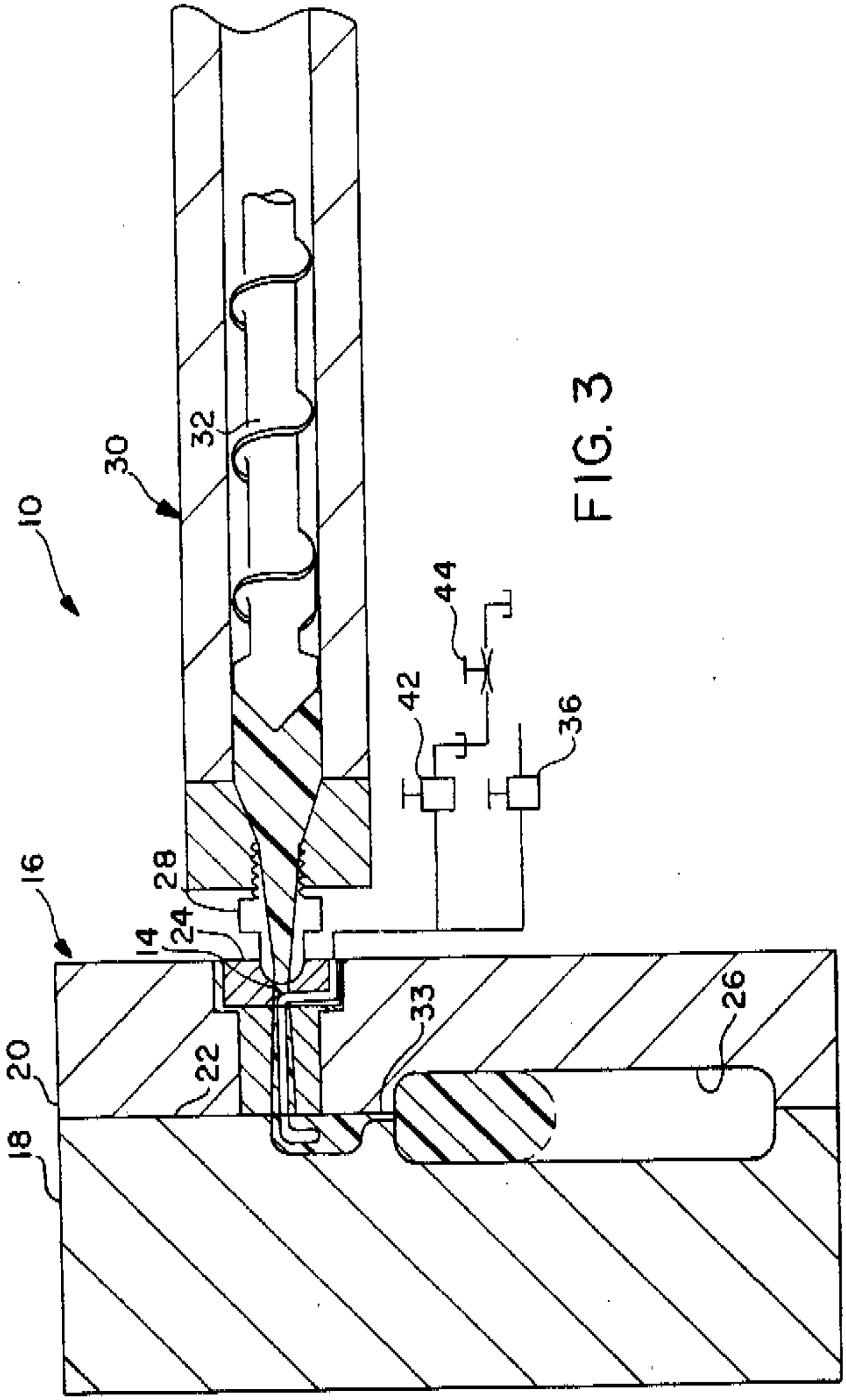


FIG. 3

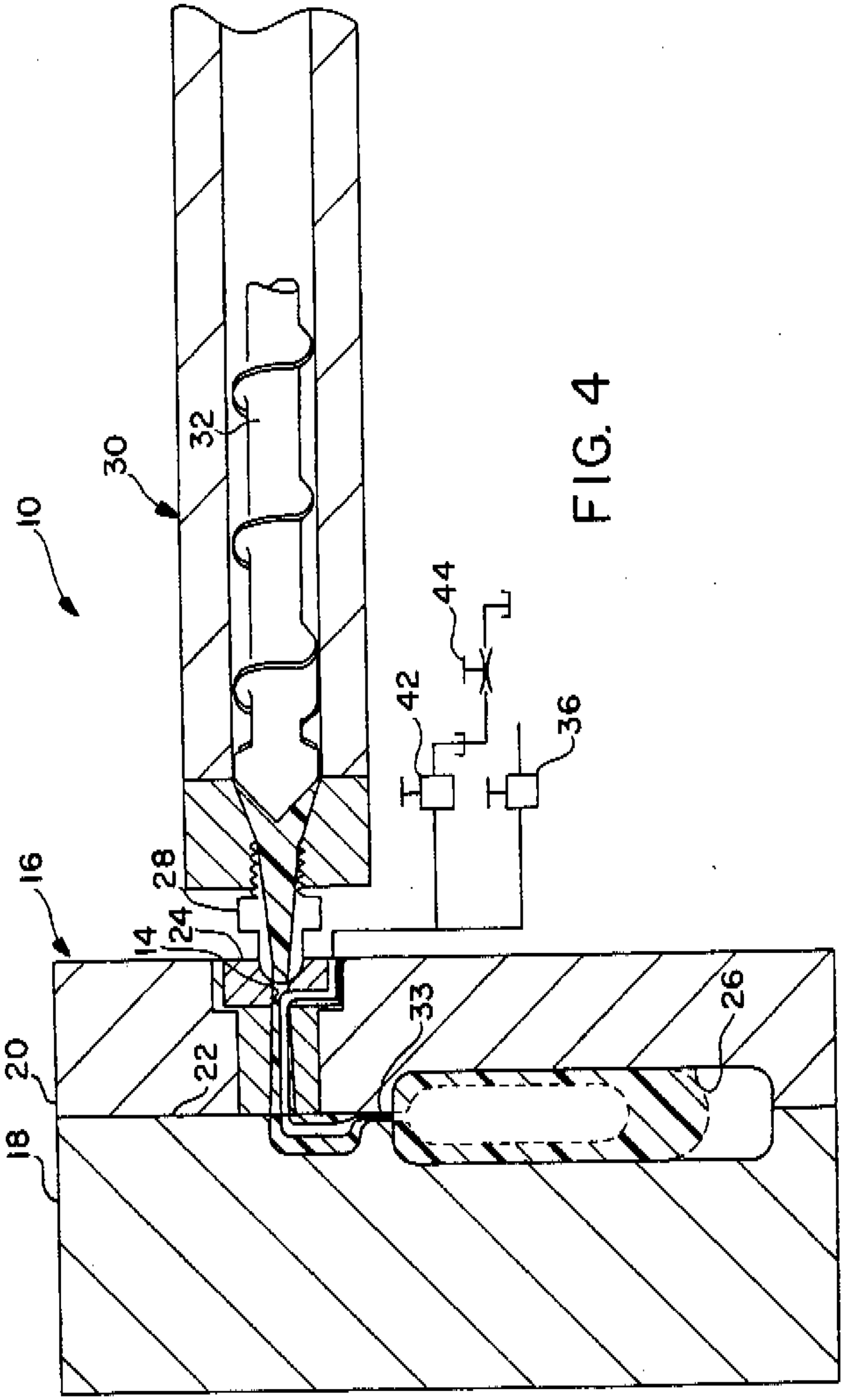


FIG. 4

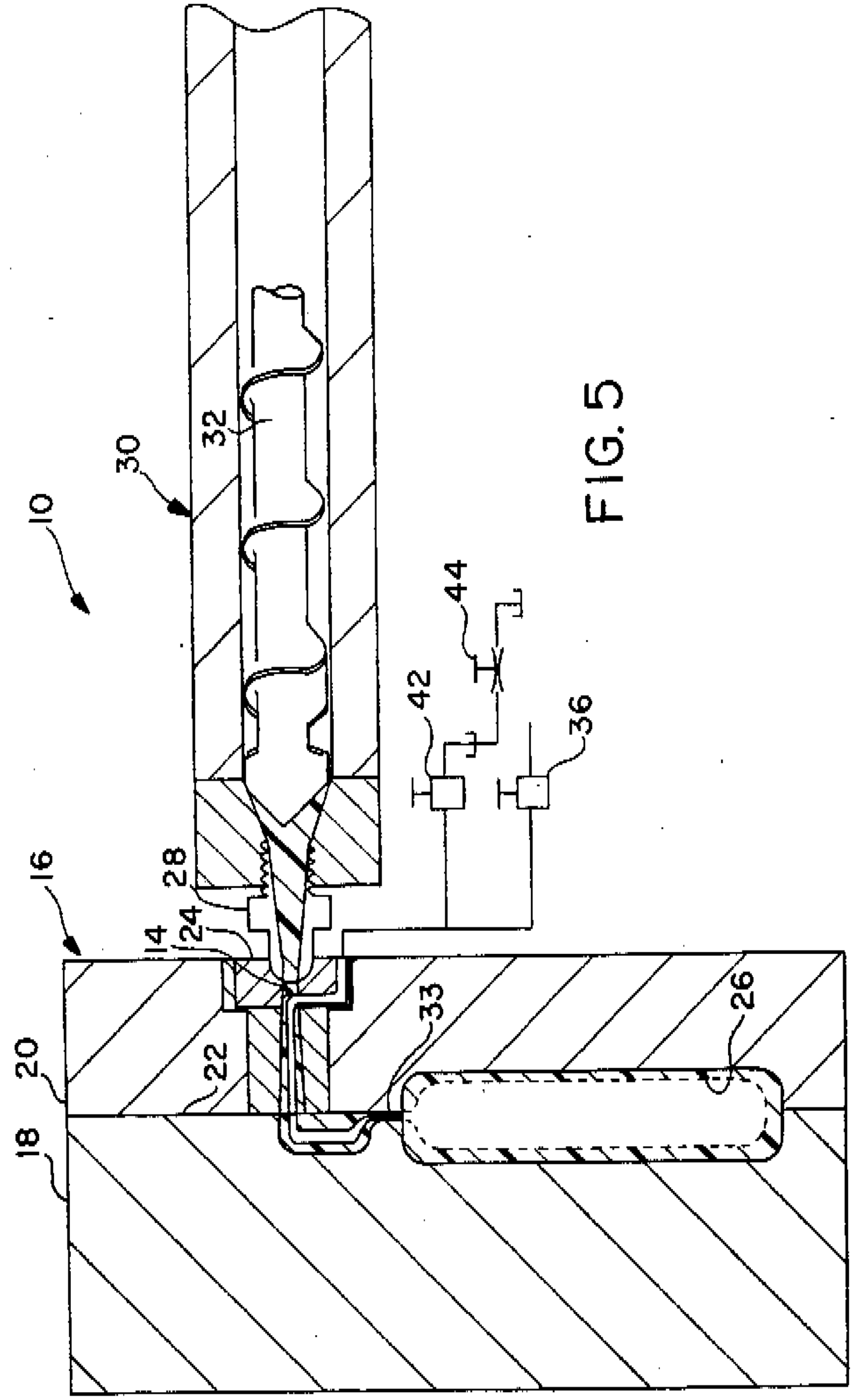


FIG. 5

METHOD FOR THE USE OF GAS ASSISTANCE IN THE MOLDING OF PLASTIC ARTICLES TO ENHANCE SURFACE QUALITY

CROSS REFERENCE TO RELATED APPLICATION

This application relates to co-pending application entitled "Method and System for the Injection Molding of Plastic Articles Utilizing a Fluid Compression Unit", U.S. Ser. No. 552,909 filed July 16, 1990 and assigned to the assignee of the present application.

TECHNICAL FIELD

This invention relates to a method of plastic injection molding and, more particularly, to a method in which pressurized gas is used to assist in the molding process.

BACKGROUND ART

The use of pressurized gas to assist in a conventional plastic injection molding process is believed to have been first made commercially practicable by the invention of Friederich disclosed in U.S. Pat. No. 4,101,617 issued July 18, 1978. The Friederich patent addressed the problem of molding hollow shaped bodies in a single injection molding operation, and taught a practicable method of introducing compressed gas along with, or just after, the injection of molten plastic resin into the article-defining cavity. Moreover, the Friederich patent solved the concern of de-pressurizing or relieving the molded article by nozzle separation. The early work of Friederich was directed to the molding of such utilitarian articles as clear plastic architectural bricks and the like. More recently, the patented Friederich process has been adapted to the molding of hollow plastic articles of various shapes and dimensions.

In its early years, the use of pressurized gas in assistance to a conventional plastic injection mold process was not recognized for all of the functional attributes which it is known to enjoy today. More specifically, during those early years, the industry gave greater focus to the use of structural foam as a specialty process for molding relatively thick-sectioned articles which would be light in weight and have acceptable surface finish, i.e., avoid sink marks associated with the conventional plastic injection molding. The range of potential applications of structural foam molding of thermoplastic material was limited, however, due to certain inherent features of such process. Among such features included, the relatively long cycle times required to cool the plastic in the mold (the foam cells serve to insulate heat transfer), and the problem of surface finish (splay, blister and swirl) associated with the foamed, molten plastic resin contacting the cool surface walls of the article-defining cavity.

In recent years, attention has returned to the use of gas assistance with conventional plastic injection molding to attain the product quality and productivity which had been hoped for With structural foam molding. The features of surface quality, lower clamp tonnage, rapid cycle times, weight reduction, material saving and minimization of part distortion or warpage can all be obtained with proper utilization of gas assistance with a conventional plastic injection molding process. The paper titled "GAS-ASSISTED INJECTION MOLDING—THE NEW THERMOPLASTIC MOLDING TECHNOLOGY FOR EXTERIOR BODY PANELS" by Dr. Ken C. Rusch, presented at the 1989 meeting of the Society of Automotive Engineers on Mar. 2, 1989, discusses in greater detail the relevant history of the use of gasassistance in connection with plastic injection molding. Another paper titled "THE AIR MOULD PROCESS—A GAS-ASSISTED INJECTION MOLDING PROCESS" by Mr. Helmut Eckardt, presented at the 1990 Structural Plastics Conference on Apr. 1-3, 1990 provides an updated history.

The impetus for the present invention was the inventor's assignment to realize the successful plastic injection molding of automobile handles which is a relatively thick molding (i.e. has a relatively thick cross section). The making of such a handle required the removal of substantial volume of plastic from the desired part and wherein the injection pressures are relatively low.

There were several practical problems facing the inventor in realizing the handle design in a hollow plastic molded piece. For example, the exterior surface of the door handle had to be "Class A" quality. Any surface degradation due to hesitation marks, blemishes or other imperfections, were unacceptable for commercial standards. Such hesitation marks typically are formed when substantially all or all of the plastic required for the part is injected into the article-defining mold cavity and only then is a gas charge injected into the mold to form the hollow plastic part. The hesitation marks are formed where the flow of plastic stops and then starts again within the article-defining cavity.

One approach to solve this problem is discussed in the U.S. Pat. No. 4,935,191 to Baxi wherein gas is introduced into the molten stream of plastic material immediately after the molten material has passed the position at which the gas is introduced. Such simultaneous injection is also discussed in UK Patent to Hendry et al GB 2158002A.

The primary problem with this approach is that it is difficult, if not impossible, to control the pressurized gas so that it does not blow clear out of the plastic rather than producing the desired gas bubble within the plastic. One reason for this is that the injection pressure of the molten plastic fluctuates during injection. Also, when a gate is employed in the mold, the pressure of the plastic is substantially higher in front of the gate than in the cavity on the opposite side of the gate (i.e. in the article-defining cavity).

DISCLOSURE OF THE INVENTION

An object of the present invention is to enhance the surface quality of a hollow plastic article by simultaneously injecting a charge of pressurized gas into a mold together with an injection of a second amount of plastic but only after a substantial first amount of plastic has been injected into an article-defining cavity of the mold. In this application, the charge of pressurized gas first prevents the flow of the first amount from stopping and then distributes the total amount of molten plastic resin in the articledefining cavity after the completion of the step of injecting the second amount of plastic. The method prevents imperfections on an exterior surface of the plastic article.

In carrying out the above object and other objects of the present invention, a method for the use of gas-assistance in the molding of hollow plastic articles for improving the surface quality of the plastic article in an injection molding system is provided. The injection molding system includes a mold having an article-defining cavity. The method includes the steps of injecting a first amount of molten plastic resin less than the total amount of molten plastic resin sufficient for the preparation of the plastic article into the cavity so that the first amount of molten plastic resin flows in the cavity. The method also includes the step of injecting a charge of pressurized gas into the mold after the step of injecting the first amount of plastic into the cavity wherein the gas charge is of pressure and quantity sufficient to enter but not exit the first amount of molten plastic resin in the cavity and sufficient to prevent the flow of the first amount of molten plastic resin in the cavity from stopping. Simultaneously with the step of injecting the charge of pressurized gas, a second amount of molten plastic resin continues to be injected into the cavity which, together with the first amount of molten plastic resin, provides the total amount sufficient for the preparation of the plastic article. The method further includes the step of continuing to inject the charge of pressurized gas to distribute the molten plastic resin in the article-defining cavity after completion of the step of injecting the second amount of molten plastic. The method prevents imperfections on an exterior surface of the plastic article. Finally, the method includes the steps of maintaining the gas charge under pressure until the article has set up in the cavity, relieving the gas pressure within the article, and removing the article from the mold.

Preferably, the ratio of the first amount of molten plastic resin to the total amount of molten plastic resin is in the range of 0.2 to 0.7 and further, preferably, is approximately 0.5.

Further objects and features of the present invention will be made known in the following description of the best mode for carrying out the invention when considered together with the drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is process flow chart showing the operative steps of the novel molding process of the present invention;

FIG. 2 is a schematic view, partially broken away and in cross-section, of a plastic injection molding system including a mold wherein plastic is accumulated in an injection molding nozzle of the system;

FIG. 3 is a schematic view of the injection molding system of FIG. 2 wherein approximately 50% of the amount of molten plastic resin required to form the plastic article has been injected into an article-defining cavity of the mold and a portion of a charge of pressurized gas has entered the mold, but not the article-defining cavity;

FIG. 4 is a schematic view of the injection molding system of FIG. 2 wherein the total amount of molten resin sufficient for the preparation of the plastic article is in the articledefining cavity along with a portion of the charge of pressurized gas; and

FIG. 5 is a schematic view of the injection molding system of FIG. 2 illustrating a hollow plastic article within the mold cavity wherein the total charge of pressurized gas has distributed the total amount of molten plastic resin in the article-defining cavity.

BEST MODE FOR CARRYING OUT THE INVENTION

FIG. 1 discloses the general sequence of steps involved in carrying out the method of the present invention. FIGS. 2 through 5 are schematic illustrations of an injection molding system, generally indicated at 10, for making plastic parts or articles having relatively large or thick crosssections wherein substantial volumes of plastic are removed from the article and the injection pressures are relatively low, such as when forming automotive handles.

The following description of the invention will correlate the method steps of FIG. 1 with the corresponding structure of FIGS. 2–5 to facilitate the disclosure. As a prefactory note, the general principles of gas-assisted injection molding are disclosed in the basic patent to Friederich U.S. Pat. No. 4,101,617, issued July 18, 1978. The present invention is an improvement based on the Friederich disclosure which addressed the basic problems of coordinating the introduction of molten plastic and pressurized gas into the mold and, thereafter, venting the interior of the whole molded article on a predictable, repeatable basis to produce articles with superior surface quality on a commercial basis.

With reference to FIG. 1, in step 12, a charge or first amount of molten plastic resin is injected into an injection aperture 14 of a mold, generally indicated at 16, of the system 10. The mold 16 typically includes mold halves 18 and 20 which are separable along a mold line 22.

In a preferred embodiment of the present invention, the injection aperture 14 is defined by a device 24 for assisting in the introduction of pressurized gas into an article-defining cavity 26 of the mold 16. Such a device is described in detail in U.S. Pat. No. 4,943,407 to Hendry, assigned to the assignee of the present application. As described in this patent, the device 24 may be positioned anywhere in the system 10 before the article-defining cavity 26 (i.e. typically in the mold runner system, but may also be located on the nozzle of the system 10).

The first charge or amount of plastic resin is injected at a pressure sufficient to partially fill the article-defining cavity 26. This amount may be in the range of 20%–70% of the total amount of plastic required to make the plastic article depending on the type of plastic, the cross section of the article and the gas pressure. Preferably, the first amount of molten resin injected into the cavity 26 is approximately 50% of the total amount of molten plastic resin sufficient for the preparation of the plastic article.

The temperature of the plastic charge is within the range of processing temperatures for the resin composition to ensure sufficient fluidity of the plastic charge. However, the plastic injection temperature cannot be so great as to cause shearing or burning of the resin composition and, consequently, degradation of the material, including dehomogenization due to separation of filler materials.

As illustrated in drawing FIGS. 2 through 5 and, as illustrated in the above-noted Hendry U.S. patent, the device 24 is adapted to seat in a sprue opening of the mold 16 and is adapted to receive the tip end 28 of a nozzle of an injection molding machine, generally indicated at 30. The injection molding machine 30 also includes an injection screw ram 32 which operates in a conventional fashion to melt the plastic resin into its molten form and inject the resulting molten plastic resin through the nozzle of the machine 30. The nozzle of the injection molding machine 30 is not illustrated as having a nozzle shutoff valve. However, it is to be understood that such a nozzle shutoff valve is preferred in some embodiments of the present invention.

In the mold 16 the molten plastic resin flows through the device 24, the sprue, a runner of the mold 16 and a gate 33 which collectively define a resin flow path which extends between the injection aperture 14 and the article-defining cavity 26.

In step 34 of FIG. 1, a charge of pressurized gas is injected into the mold 16 after opening a valve 36 which is in communication with a source (not shown) of pressurized gas such as nitrogen gas. Preferably, the injection of gas is performed by the system disclosed in the above-noted application referenced by U.S. Ser. No. 552,909 filed July 16, 1990.

The opening of the valve 36 is preferably synchronized with the ram 32 Which moves at a substantially constant velocity during its stroke. The valve 36 may be controlled to open under control of a limit switch operatively coupled to be actuated when the position of the ram 32 corresponds to the first amount of plastic being located in the cavity 26.

As illustrated in FIG. 3, the nitrogen gas is of a pressure and quantity sufficient to enter the resin flow path and, as further illustrated in FIG. 4, to enter, but not exit, the first amount of molten plastic resin in the article-defining cavity 26. The pressurized gas prevents the flow of the first amount of molten plastic resin from stopping in the cavity 26. Alternately, the nitrogen gas is directly injected into the first amount of plastic resin in the cavity 26 by a pin (not shown) which extends into the cavity 26 and would be covered by the first amount of molten plastic resin when the pressurized gas is initially injected.

As illustrated at step 36 of FIG. 1, at the same time as (i.e. simultaneously with) step 34, a second amount, of molten plastic resin is injected into the mold cavity 26. It is to be understood that since the ram 32 moves with a substantially constant velocity, the second amount flows continuously folloWing the first amount of plastic resin.

The first and second amounts of molten plastic resin together define a total amount of molten plastic resin sufficient for the preparation of the plastic article. All of the plastic required for the formation of the plastic article is located in the article-defining cavity 26 along with as portion of the charge of pressurized gas as illustrated in FIG. 4.

As illustrated in FIG. 5 and step 38 of FIG. 1, the charge of pressurized gas continues to be injected into the article-defining cavity 26 to distribute the total amount of molten plastic resin in the article-defining cavity 26. This final distribution of molten plastic resin in the articledefining cavity 26 occurs after the completion of step 36 of injecting the second amount of molten plastic material.

The simultaneous injection of the second amount of molten plastic resin, together with the injection of the charge of pressurized gas prevents the flow of plastic resin in the mold cavity from stopping and, consequently, allows the formation of an exterior surface of the plastic article to be free of imperfections to meet automotive company standards on Class A surface finish. The substantial first amount of plastic in the cavity 26 prior to step 34 prevents blowout (i.e. the gas makes its way outside the plastic to the surfaces of the mold defining the cavity 26).

In step 39 of FIG. 1, the pressurized gas is maintained in the article Within the article-defining cavity 26 while the plastic solidifies. The presence of the pressurized gas within the article during solidification urges the plastic into intimate contact with the walls of the article-defining cavity to further promote surface quality. The gas

pressure counters the normal tendency of the plastic to shrink while cooling and leave blemishes in the surface of the finished article.

In step 40 of FIG. 1, the gas pressure within the article is relieved and the finished article is removed from the mold 16. Preferably, the gas is vented upon opening valve 42 to allow the gas to vent through the same passageway in the device 24 through which the gas entered the mold. Venting can be performed slowly in a controlled fashion by the provision of needle valve 44 in series with the valve 42.

The depressurization of the article can be performed in many different ways, such as by nozzle retraction, piercing, shearing, or like mechanical operation applied to the sprue or the runner and the like.

Upon depressurization or relieving the article, the molding including the finished article is removed from the mold 16. The appendaqes of the runner and the sprue may be separated from the finished article in accordance with conventional operations.

The advantages of the method as described above are numerous. For example, the method of the present invention keeps the molten plastic resin moving within the article-defining cavity 26 after the injection of plastic starts. This is done by starting gas flow before all of the molten plastic accumulated in the machine 30 is injected by the screw ram 32 into the mold 16. This eliminates hesitation or shadow marks which may form on the exterior surface of the article. Such marks indicate where the plastic flow stops and then starts again. As previously noted, such marked parts are not acceptable commercial products since they do not have a Class A finish.

Also, as previously noted, the present invention works particularly well with large, thick cross-sectional moldings wherein substantial volumes of plastic are removed from the article and replaced by hollow portions and wherein injection pressures are relatively low (i.e. 1000 psi–5000 psi).

The invention has been described in an illustrative manner, and, it is to be understood that, the terminology which has been used is intended to be in the nature of words of description, rather than of limitation.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is, therefore, to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A method for the use of gas-assistance in molding a hollow plastic article for improving surface quality of the plastic article in an injection molding system including a mold having an article-defining cavity, the method comprising the steps of:

injecting a first amount of molten plastic resin less than a total amount of molten plastic resin sufficient for the preparation of the plastic article into the cavity, so that the first amount of molten plastic resin flows in the cavity;

injecting a charge of pressurized gas into the mold after the step of injecting the first amount of plastic into the cavity, said gas charge being of pressure and quantity sufficient to enter but not exit the first amount of molten plastic resin in the cavity and sufficient to prevent the flow of first amount of molten plastic resin in the cavity from stopping;

continuing to inject a second amount of molten plastic resin into the cavity simultaneously with the step of injecting the charge of pressurized gas, the first and second amounts of molten plastic resin providing the total amount sufficient for the preparation of the plastic article;

continuing to inject the charge of pressurized gas into the mold to distribute the total amount of molten plastic resin in the cavity after completion of the step of injecting the second amount of molten plastic resin whereby imperfections on an exterior surface of the plastic article are prevented;

maintaining the gas charge under pressure within the article until the article has set up in the cavity to form the article;

relieving the gas pressure within the article; and

removing the article form the mold wherein a ratio of the first amount of molten plastic resin to the total amount of molten plastic resin is in a range of 0.2 to 0.7; and wherein the pressurized gas has a pressure between approximately 1000 psi and 5000 psi.

2. The method as claimed in claim 1 wherein the ratio is approximately 0.5.

3. The method as claimed in claim 1 wherein the mold includes an injection aperture and wherein the first amount of molten plastic resin flows through the injection aperture, along a resin flow path extending from the injection aperture to a gate adjacent the cavity, through the gate and into the cavity.

4. The method as claimed in claim 1 wherein the step of relieving the gas pressure takes place at a controlled rate.

5. The method as claimed in claim 1 wherein the step of relieving the gas pressure is accomplished through a fluid passage extending through a device which at least partially defines a resin flow path in the mold.

6. The method as claimed in claim 3 wherein the second amount of molten plastic is injected through the injection aperture along the resin flow path.

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[54] **METHOD OF INJECTING MOLDING**

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[*] Notice: The portion of the term of this patent subsequent to Jul. 16, 2008 has been disclaimed.

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[52] **U.S. Cl.** **264/572**; 264/328.8; 264/328.12; 264/328.13

[58] **Field of Search** 264/85, 328.8, 328.12, 264/500, 572, 328.13; 425/812

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[57] **ABSTRACT**

A method and system for the injection molding of plastic articles in an injection molding system including a pneumatically operated gas compression unit having a high pressure gas receiver. The injection molding system includes a resin injection nozzle and a mold having an injection aperture and mold cavity for receiving molten resin from the nozzle. The gas compression unit includes a gas booster which pressurizes a first charge of gas to the pressure setting of a pressure switch. The gas receiver stores the first charge of pressurized gas at a pressure level within a predetermined range of pressures. At least one fluid pressure reducing valve reduces the pressure of the gas as it is communicated from the fluid receiver to an orifice in the mold to an acceptable level for molding the article. The gas compression unit is capable of servicing a plurality of injection molding machines and corresponding molds when a like plurality of pressure reducing valves are provided.

5 Claims, 2 Drawing Sheets