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### **MOLDED ARTICLE WITH SELECTIVELY VARIED CORE LAYER GEOMETRY AND HOT RUNNER NOZZLES FOR PRODUCING SAME**

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#### **Abstract**

A molded article suitable for subsequent blow-molding into a final-shaped container. The article includes a neck portion; a gate portion; and a body portion extending between the neck portion and the gate portion, at least a majority of the body portion having an overall shape which is symmetric about a body axis extending longitudinally through a center of the body portion. The body portion includes an inner exterior layer and an outer exterior layer of a first polymeric material; and a core layer of a second polymeric material disposed between the inner exterior layer and the outer exterior layer. A radial thickness or a material of the core layer is selectively varied to govern non-uniform blow molding of the molded article into the final-shaped container.

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## Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a divisional of U.S. patent application Ser. No. 16/623,145 filed Dec. 16, 2019, which is the U.S. National Stage of PCT/CA2018/050756, filed Jun. 21, 2018, which claims priority from U.S. Provisional patent application Ser. No. 62/523,875 filed Jun. 23, 2017, the disclosures of which are incorporated herein by reference.

### FIELD OF THE TECHNOLOGY

[0002] The present technology relates to multi-layer molded articles suitable for subsequent blow-molding into final-shaped containers. More specifically the present technology relates to molded articles with core layers that are formed to selectively affect subsequent blow molding properties when the multi-layer molded article is processed into the final-shaped container.

### BACKGROUND

[0003] Molding is a process by virtue of which a molded article can be formed from molding material by using a molding system. Various molded articles can be formed by using the molding process, such as an injection molding process. One example of a molded article that can be formed, for example, from polyethylene terephthalate (PET) material, is a preform that is capable of being subsequently blown into a beverage container, such as, a bottle and the like. In other words, the preform is an intermediary product that is then processed into the final-shaped container by a stretch blow-molding process (as an example). During the stretch blow-molding process, the material of the preform behaves with certain properties (such as stretch ratio, which depends on the reheating temperature, etc).

[0004] As one can appreciate, a typical preform is circularly-symmetric around its longitudinal axis. Some final-shaped molded articles are also circularly-symmetric. For example, a beverage container (a bottle) for still or sparkling beverage is substantially symmetric around its longitudinal axis (when standing on a shelf, for example). Other finally-shaped containers are not circularly-symmetric. Examples of such non-circularly-symmetric finally-shaped containers include, but are not limited to: containers for household cleaning liquids (such as glass cleaning liquid, toilet bowl cleaning liquids, etc.), containers for personal care products (shampoos, conditioners, etc.) and the like.

[0005] Blow-molding a symmetric preform into an asymmetric container may induce structural and/or stretch blow-molding process related challenges, such as weaker walls where the preform has been expanded the most.

[0006] Some of the preforms (and hence the finally-shaped containers) are made from a single molding material. Such as, the aforementioned preforms that are stretch blow-molded into beverage container for still or sparkling beverages are typically made from a single material-PET. PET is

well suited for such applications. However, PET is not suited ideally for other applications. For that matter, for certain applications, no single material is a viable option (either because it lacks certain properties or because it would be commercially non-viable). It is, thus, also known to create multi-material preforms, where another material (typically called a “core material”) is added and “sandwiched” between inner and outer layers of one or more other material(s).

[0007] As an example, certain materials can be chosen as the core layer to enhance oxygen impermeability (e.g. barrier material, such as EVOH or PGA), to enhance light impermeability, or the like.

## SUMMARY

[0008] It is an object of the present invention to ameliorate at least some of the inconveniences present in the prior art.

[0009] Without wishing to be bound to any specific theory, embodiments of the present technology have been developed based on developers' appreciation that geometry of the core/barrier layer can be instrumental in selectively controlling stretching or blow-molding of a final-shaped container. The developers have further appreciated that controlled non-uniform geometry of the core layer can be utilized for aesthetic purposes, including creating selective color variation in the final-shaped container.

[0010] According to a first broad aspect of the present technology, there is provided a molded article suitable for subsequent blow-molding into a final-shaped container. The article includes a neck portion; a gate portion; and a body portion extending between the neck portion and the gate portion, at least a majority of the body portion having an overall shape which is symmetric about a body axis extending longitudinally through a center of the body portion, at least the body portion including an inner exterior layer and an outer exterior layer of a first polymeric material; and a core layer of a second polymeric material disposed between at least a portion of the inner exterior layer and the outer exterior layer, a radial thickness of the core layer being selectively varied to govern non-uniform blow molding of the molded article into the final-shaped container.

[0011] In some embodiments of the molded article, the rate of thermal crystallization of the first polymeric material is substantially less than that of the second polymeric material; and the second polymeric material includes at least one of a strain-crystallizable homopolymer, copolymer, and blend of polyethylene terephthalate (PET).

[0012] In some embodiments of the molded article, at least a majority of the neck portion is composed of the first polymeric material and is free of the second polymeric material.

[0013] In some embodiments of the molded article, the second polymeric material has a substantially higher intrinsic viscosity than the first polymeric material.

[0014] In some embodiments of the molded article, the radial thickness of the core layer varies about the body axis.

[0015] In some embodiments, the core layer has localized regions of increased radial thickness.

[0016] In some embodiments of the molded article, the radial thickness of the core layer has a non-symmetrical annular form about the body axis.

[0017] In some embodiments of the molded article, the radial thickness of the core layer has a symmetrical annular form about the body axis.

[0018] In some embodiments of the molded article, the core layer has a semi-annular core layer.

[0019] In some embodiments of the molded article, the radial thickness of the core layer varies in an axial direction.

[0020] In some embodiments of the molded article, the core layer is interrupted such that the radial thickness of the core layer decreases to zero at least one location; and the inner exterior layer and the outer exterior layer are in contact at the at least one location.

[0021] In some embodiments of the molded article, the molded article further includes a transition portion extending between the neck portion and the body portion; and wherein the transition portion includes a transition inner layer and a transition outer layer of the first polymeric material;

and a transition core layer of the second polymeric material disposed between at least a portion of the inner exterior layer and the outer exterior layer.

[0022] In some embodiments of the molded article, the transition core layer is interrupted such that the radial thickness of the transition core layer decreases to zero at least one location.

[0023] According to another broad aspect of the present technology, there is provided a molded article suitable for subsequent blow-molding into a final-shaped container. The molded article includes a neck portion; a gate portion; and a body portion extending between the neck portion and the gate portion, at least the body portion including an inner exterior layer and an outer exterior layer of a first polymeric material; and a core layer of a second polymeric material disposed between at least a portion of the inner exterior layer and the outer exterior layer, the rate of thermal crystallization of the first polymeric material being substantially less than that of the second polymeric material, the second polymeric material including at least one of a strain-crystallizable homopolymer, copolymer, and blend of polyethylene terephthalate (PET).

[0024] According to yet another broad aspect of the present technology, there is provided a molded article suitable for subsequent blow-molding into a final-shaped container. The molded article includes a neck portion; a gate portion; and a body portion extending between the neck portion and the gate portion, at least the body portion including an inner exterior layer and an outer exterior layer of a first polymeric material; and a core layer of a second polymeric material disposed between at least a portion of the inner exterior layer and the outer exterior layer, the second polymeric material having a substantially higher intrinsic viscosity than the first polymeric material.

[0025] According to yet another broad aspect of the present technology, there is provided a molded article suitable for subsequent blow-molding into a final-shaped container. The molded article includes a neck portion; a gate portion; and a body portion extending between the neck portion and the gate portion, at least a majority of the body portion having an overall shape which is symmetric about a body axis extending longitudinally through a center of the body portion, at least the body portion including: an inner exterior layer and an outer exterior layer of a first polymeric material; and a core layer of a second polymeric material disposed between at least a portion of the inner exterior layer and the outer exterior layer, a radial thickness of the core layer being selectively varied to produce variation in color distribution in the final-shaped container.

[0026] In some embodiments, the first polymeric material has a first color; and the second polymeric material has a second color different from the first color.

[0027] In some embodiments, the radial thickness of the core layer varies about the body axis.

[0028] In some embodiments, the radial thickness of the core layer has a non-symmetrical annular form about the body axis.

[0029] In some embodiments, the core layer has localized regions of increased radial thickness.

[0030] According to yet another broad aspect of the present technology, there is provided a hot runner nozzle for conveying melt to a mold cavity. The hot runner nozzle includes an inner nozzle insert defining an inner flow channel; an intermediate nozzle insert disposed around the inner nozzle insert, the intermediate nozzle insert and the inner nozzle insert defining an intermediate flow channel; and an outer nozzle insert disposed around the intermediate nozzle insert, the outer nozzle insert and the intermediate nozzle insert defining an outer flow channel, the intermediate nozzle insert and the inner nozzle insert cooperating to define an intermediate outlet, at least one of the inner nozzle insert and the intermediate nozzle insert further defining at least one aperture disposed upstream from the intermediate outlet, at least one aperture being arranged to fluidly connect with at least one of the inner flow channel and the outer flow channel.

[0031] In some embodiments, in use, when conveying the melt to the mold cavity: a first stream of melt of a first polymeric material flows through and exits the inner flow channel and the outer flow channel; a second stream of melt of a second polymeric material flows through the intermediate flow channel; and at least a portion of the second stream of melt passes through the at least one

aperture from the intermediate flow channel to at least one of the inner flow channel and the outer flow channel.

[0032] In some embodiments, the intermediate nozzle insert defines the at least one aperture; and when in use, at least a portion of the second stream of melt passes through the at least one aperture from the intermediate flow channel to the outer flow channel.

[0033] In some embodiments, the at least one aperture includes a first plurality of apertures defined along a first line extending longitudinally along the intermediate nozzle insert; and a second plurality of apertures defined along a second line extending longitudinally along the intermediate nozzle insert, the first line and the second line being separate from each other.

[0034] In some embodiments, the inner nozzle insert defines the at least one aperture; and when in use, at least a portion of the second stream of melt passes through the at least one aperture from the intermediate flow channel to the inner flow channel.

[0035] In some embodiments, the at least one aperture includes a first plurality of apertures defined along a first line extending longitudinally along the inner nozzle insert; and a second plurality of apertures defined along a second line extending longitudinally along the inner nozzle insert, the first line and the second line being separate from each other.

[0036] In some embodiments, the mold cavity is for defining, in use, a molded article having a core layer and a skin layer surrounding the core layer, the core layer being formed from the second polymeric material flowing through the intermediate flow channel, the core layer having a non-uniform radial thickness about a longitudinal axis of the molded article.

[0037] In some embodiments, the at least one aperture includes a plurality of apertures that fluidly connect the intermediate flow channel with at least one of the inner flow channel and the outer flow channel.

[0038] According to yet another broad aspect of the present technology, there is provided a hot runner nozzle for conveying melt to a mold cavity. The hot runner nozzle includes an inner nozzle insert defining an inner flow channel, the inner flow channel including an inner outlet; an intermediate nozzle insert disposed around the inner nozzle insert, the intermediate nozzle insert and the inner nozzle insert defining an intermediate flow channel, the intermediate flow channel including an intermediate outlet; and an outer nozzle insert disposed around the intermediate nozzle insert, the outer nozzle insert and the intermediate nozzle insert defining an outer flow channel, the outer flow channel including an outer outlet, the inner nozzle insert being formed such that the intermediate outlet has a non-uniform cross-section.

[0039] In some embodiments, the mold cavity is for defining, in use, a molded article having a core layer and a skin layer surrounding the core layer, the core layer being formed from material flowing through the intermediate flow channel, the material having a non-uniform radial thickness about the axis.

[0040] In some embodiments, the inner outlet, the intermediate outlet, and the outer outlet are immediately adjacent to one another.

[0041] In some embodiments, the inner nozzle insert is formed such that the intermediate outlet extends only partially around a longitudinal axis of the hot runner nozzle.

[0042] In some embodiments, the inner nozzle insert has an exterior surface partially defining the intermediate flow channel; and the exterior surface has an elliptical form, a center of the elliptical form surface being off-center from a longitudinal axis of the hot runner nozzle.

[0043] In some embodiments, the inner outlet and the outer outlet are arranged concentrically.

[0044] In some embodiments, the intermediate outlet is disposed between a portion of the concentrically arranged inner and outer outlets.

[0045] In some embodiments, in use, when transferring the melt to the mold cavity: a first stream of melt of a first polymeric material flows through and exits the inner flow channel and the outer flow channel; a second stream of melt of a second polymeric material flows through and exits the intermediate flow channel, the second polymeric material forming a core layer of a molded product

produced by the melt in the mold cavity; and the first stream of melt and the second stream of melt intersect at a combination area.

[0046] In some embodiments, the mold cavity is for defining, in use, a molded article having a core layer and a skin layer surrounding the core layer, the core layer being formed from the second polymeric material flowing through the intermediate flow channel, the core layer having a non-uniform radial thickness about a longitudinal axis of the molded article.

[0047] According to yet another broad aspect of the present technology, there is provided a hot runner nozzle for conveying melt to a mold cavity. The hot runner nozzle includes an inner nozzle insert defining an inner flow channel; an intermediate nozzle insert disposed around the inner nozzle insert, the intermediate nozzle insert and the inner nozzle insert defining an intermediate flow channel; and an outer nozzle insert disposed around the intermediate nozzle insert, the outer nozzle insert and the intermediate nozzle insert defining an outer flow channel, flow of material through the intermediate flow channel, when the hot runner nozzle is in use, being non-uniformly distributed about a longitudinal axis of the hot runner nozzle, the non-uniformity of the flow being attributable to surfaces of the intermediate nozzle insert and the inner nozzle which define the intermediate flow channel, the mold cavity being for defining, in use, a molded article having a core layer and a skin layer surrounding the core layer, the core layer formed from material flowing through the intermediate flow channel, the core layer having a non-uniform radial thickness about a longitudinal axis of the molded article.

[0048] These and other aspects and features of non-limiting embodiments of the present technology will now become apparent to those skilled in the art upon review of the following description of specific non-limiting embodiments of the technology in conjunction with the accompanying drawings.

[0049] Embodiments of the present technology each have at least one of the above-mentioned object and/or aspects, but do not necessarily have all of them. It should be understood that some aspects of the present technology that have resulted from attempting to attain the above-mentioned object may not satisfy this object and/or may satisfy other objects not specifically recited herein.

[0050] Additional and/or alternative features, aspects and advantages of embodiments of the present technology will become apparent from the following description, the accompanying drawings and the appended claims.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

[0051] The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

[0052] A better understanding of the embodiments of the present technology (including alternatives and/or variations thereof) may be obtained with reference to the detailed description of the non-limiting embodiments along with the following drawings, in which:

[0053] FIG. 1 is a cross-sectional view of a multilayer preform as known in the prior art;

[0054] FIG. 2 is a top view schematic diagram of an injection molding machine, which can be adapted for producing implementations of the non-limiting embodiments of the present technology;

[0055] FIG. 3A is a longitudinal cross-sectional view of a multilayer preform according to one embodiment of the present technology;

[0056] FIG. 3B is a horizontal cross-sectional view of the multilayer preform of FIG. 3A, taken along line 3B-3B of FIG. 3A;

[0057] FIG. 4A is a longitudinal cross-sectional view of a multilayer preform according to another embodiment of the present technology;

[0058] FIG. 4B is a horizontal cross-sectional view of the multilayer preform of FIG. 4A, taken along line 4B-4B of FIG. 4A;

[0059] FIG. 5A is a longitudinal cross-sectional view of a multilayer preform according to yet another embodiment of the present technology;

[0060] FIG. 5B is a horizontal cross-sectional view of the multilayer preform of FIG. 5A, taken along line 5B-5B of FIG. 5A;

[0061] FIG. 6A is a longitudinal cross-sectional view of a multilayer preform according to yet another embodiment of the present technology;

[0062] FIG. 6B is a horizontal cross-sectional view of the multilayer preform of FIG. 6A, taken along line 6B-6B of FIG. 6A;

[0063] FIG. 6C is a front side elevation view of a blow-molded product blown from the preform of FIG. 6A;

[0064] FIG. 7A is a longitudinal cross-sectional view of a multilayer preform according to yet another embodiment of the present technology;

[0065] FIG. 7B is a front side elevation view of a blow-molded product blown from the preform of FIG. 7A;

[0066] FIG. 8A is a longitudinal cross-sectional view of a multilayer preform according to yet another embodiment of the present technology;

[0067] FIG. 8B is a horizontal cross-sectional view of the multilayer preform of FIG. 8A, taken along line 8B-8B of FIG. 8A;

[0068] FIG. 8C is a front side elevation view of a blow-molded product blown from the preform of FIG. 8A;

[0069] FIG. 9A is a longitudinal cross-sectional view of a multilayer preform according to yet another embodiment of the present technology;

[0070] FIG. 9B is a horizontal cross-sectional view of the multilayer preform of FIG. 9A, taken along line 9B-9B of FIG. 9A;

[0071] FIG. 9C is a front side elevation view of a blow-molded product blown from the preform of FIG. 9A;

[0072] FIG. 10 is a longitudinal cross-sectional view of a multilayer preform according to yet another embodiment of the present technology;

[0073] FIG. 11 is a longitudinal cross-sectional view of a multilayer preform according to yet another embodiment of the present technology;

[0074] FIG. 12 is a cross section of a hot runner nozzle (the cross section being taken along an operational axis of the hot runner nozzle), the hot runner nozzle being suitable for implementing embodiments of the present technology;

[0075] FIG. 13 is a cross section of the hot runner nozzle of FIG. 12 taken along line 13-13 of FIG. 12, the hot runner nozzle being configured for producing preforms with the radial thickness of the core layer that does not vary about the operational axis;

[0076] FIG. 14 is a cross section of the hot runner nozzle of FIG. 12 taken along line 13-13 of FIG. 12, the hot runner nozzle being configured for producing preforms with the radial thickness of the core layer that varies about the operational axis;

[0077] FIGS. 15A through to 15D depict a sequence of re-positioning of the valve stem to selectively undulate the core layer, the re-positioning of the valve stem being used for forming the shape of the core layer in some non-limiting embodiments of the present technology;

[0078] FIG. 16A is a photograph, produced by a backlit optical comparator, of a cross-section of another non-limiting embodiment of a molded article according to the present technology;

[0079] FIG. 16B is a line drawing representation of the cross-section of FIG. 16A;

[0080] FIG. 16C is a bottom plan view photograph of the molded article of FIG. 16A;

[0081] FIG. 16D is a line drawing representation of the photograph of FIG. 16C;

[0082] FIG. 17 is a cross section of another embodiment of a hot runner nozzle (the cross section

being taken along an operational axis of the hot runner nozzle), the hot runner nozzle being suitable for implementing embodiments of the present technology;

[0083] FIG. **18** is a perspective view of an intermediate nozzle insert of the hot runner nozzle of FIG. **17**;

[0084] FIG. **19** is a side view of another embodiment of an intermediate nozzle insert of a hot runner nozzle, the nozzle insert and the hot runner nozzle being suitable for implementing embodiments of the present technology;

[0085] FIG. **20** is a cross-sectional view of the intermediate nozzle insert of FIG. **19**, taken along line **20-20** of FIG. **19**;

[0086] FIG. **21** is a perspective view of the intermediate nozzle insert of FIG. **19**;

[0087] FIG. **22** is a side view of an intermediate nozzle insert of yet another embodiment of an intermediate nozzle insert of a hot runner nozzle, the nozzle insert and the hot runner nozzle being suitable for implementing embodiments of the present technology;

[0088] FIG. **23** is a cross-sectional view of the intermediate nozzle insert of FIG. **22**, taken along line **23-23** of FIG. **22**;

[0089] FIG. **24** is a side view of yet another embodiment of an intermediate nozzle insert of a hot runner nozzle, the nozzle insert and the hot runner nozzle being suitable for implementing embodiments of the present technology;

[0090] FIG. **25** is a cross-sectional view of the intermediate nozzle insert of FIG. **24**, taken along line **25-25** of FIG. **24**;

[0091] FIG. **26** is a cross section of yet another embodiment of a hot runner nozzle (the cross section being taken along an operational axis of the hot runner nozzle), the hot runner nozzle being suitable for implementing embodiments of the present technology;

[0092] FIG. **27** is a cross-sectional view of an intermediate nozzle insert of a hot runner nozzle (the cross section being taken along an operational axis of the hot runner nozzle) illustrating various aperture embodiments;

[0093] FIGS. **28** and **29** are perspective views of an embodiment of an inner nozzle insert of a hot runner nozzle suitable for implementing embodiments of the present technology;

[0094] FIG. **30** is a bottom plan view of the inner nozzle insert of FIG. **28**; and

[0095] FIG. **31** is a cross-sectional view of the inner nozzle insert of FIG. **28** arranged in a hot runner nozzle, taken along line **31-31** of FIG. **30**.

#### DETAILED DESCRIPTION

[0096] With reference to FIG. **1**, there is depicted a molded article **50** in cross-section, specifically a multilayer preform **50**, produced by a molding machine as known in the prior art. The prior art multilayer preform **50** is described herein to provide a general structure of a molded article suitable for subsequent blow-molding; specifics of molded articles according to the present technology will be described in more detail below.

[0097] The multilayer preform **50** is produced by an injection molding machine **100**, described below with reference to FIG. **2**. It is contemplated that multilayer preforms **50** could be produced by another type of molding machine (such as extrusion blow-molding, transfer-blow molding and the like).

[0098] The multilayer preform **50** consists of a neck portion **32**, a gate portion **36** (i.e. “base”) and a body portion **34** extending between the neck portion **32** and the gate portion **36**. The gate portion **36** is associated with a substantially spherical shape that terminates in a vestige portion **38**.

Naturally, the gate portion **36** can be executed in another form-factor (such as substantially conical, frusto-conical or the like). The body portion **34** of the multilayer preform **50** is formed by three layers. As will be described below, portions of the body portion **34** could be formed by more or fewer layers, depending on the implementation.

[0099] On exterior sides, the body portion **34** has an outer exterior skin layer **20** and an inner exterior skin layer **25**. The skin layers **20**, **25** can be made of various materials. For example, in



multilayer preforms **50** for making beverage containers, the skin layers **20**, **25** are made of virgin polyethylene terephthalate (PET), which is approved by the FDA for use in contact with foodstuffs. It is contemplated that the skin layers **20**, **25** could be made of various other materials, including any appropriate polymer resins and thermoplastics, as will be appreciated by those skilled in the art.

[0100] The multilayer preform **50** has a cavity identification number **15** imprinted in the skin layer **25**. Even though the cavity identification number **15** is depicted to be located in the neck portion **32**, this does not need to be so in alternative embodiments of the present technology. In alternative embodiments, the cavity identification number **15** can be located anywhere within the gate portion **36** or the body portion **34**. It is noted that the cavity identification number **15** can be omitted altogether.

[0101] As will be described below, each cavity **118** of one or more mold cavities **118** of the injection molding machine **100** has a cavity origin insert which imprints the cavity identification number **15** of each cavity **118**, each cavity identification number **15** being unique to each cavity **118**.

[0102] The skin layers **20**, **25** surround a core layer **40**. The core layer **40** is generally made of a different material, or a different state of the same material, than the skin layers **20**, **25**. At a top end of the preform **50**, the core layer **40** begins at a leading edge **42**. At a bottom end (typically called a “gate portion”) of the preform **50**, the core layer **40** terminates at a trailing edge **44** (i.e. “open dome”). In other non-limiting embodiments, not shown, the core layer may extend around the entirety of the gate portion (i.e. “encapsulated”). As will be described below, the core layer **40** is used to impart different properties to the preforms **50**, such as increased rigidity. The core layer **40**, in some embodiments, can act as a barrier layer in the eventual blow-molded container blown from the preform **50**. In such cases, the barrier layer can help to prevent transmission of, for example, oxygen or light into an interior of the blow-molded container. The core layer **40** can also be made from any one of various appropriate thermoplastics and polymer resins as will be appreciated by those skilled in the art. It is contemplated that the core layer **40** could also contain various additives, coloring, or property adjusting agents to affect different properties of the multilayer preform **50**.

[0103] With reference to FIG. 2, there is depicted a non-limiting embodiment of the injection molding machine **100** which can be adapted to produce molded articles according to embodiments of the present technology. However, it should be understood that in alternative non-limiting embodiments, the injection molding machine **100** may comprise other types of molding systems, such as, but not limited to, compression molding systems, compression injection molding systems, transfer molding systems, metal molding systems and the like.

[0104] As seen in FIG. 2, the injection molding machine **100** comprises a fixed platen **102** and a movable platen **104**. In some embodiments of the present technology, the injection molding machine **100** may include a third non-movable platen (not depicted). Alternatively or additionally, the injection molding machine **100** may include turret blocks, rotating cubes, turning tables and the like (all not depicted but known to those of skill in the art).

[0105] The injection molding machine **100** further comprises an injection unit **106** for plasticizing and injection of the molding material. The injection unit **106** can be implemented as a single stage or a two-stage injection unit. The injection molding machine **100** can include two instances of the injection unit **106**—each one for preparing and injection a different type of molding material, i.e. a first molding material and a second molding material.

[0106] In operation, the movable platen **104** is moved towards and away from the fixed platen **102** by means of stroke cylinders (not shown) or any other suitable means. Clamp force (also referred to as closure or mold closure tonnage) can be developed within the injection molding machine **100**, for example, by using tie bars **108**, **110** (typically, four tie bars **108**, **110** are present in the injection molding machine **100**) and a tie-bar clamping mechanism **112**, as well as (typically) an associated

hydraulic system (not depicted) that is usually associated with the tie-bar clamping mechanism **112**. It will be appreciated that clamp tonnage can be generated using alternative means, such as, for example, using a column-based clamping mechanism, a toggle-clamp arrangement (not depicted) or the like.

[0107] A first mold half **114** can be associated with the fixed platen **102** and a second mold half **116** can be associated with the movable platen **104**. In the non-limiting embodiment of FIG. 2, the first mold half **114** comprises the one or more mold cavities **118**. As will be appreciated by those of skill in the art, the one or more mold cavities **118** may be formed by using suitable mold inserts (such as a cavity insert, a gate insert and the like) or any other suitable means. As such, the first mold half **114** can be generally thought of as a “mold cavity half”.

[0108] The second mold half **116** comprises one or more mold cores **120** complementary to the one or more mold cavities **118**. As will be appreciated by those of skill in the art, the one or more mold cores **120** may be formed by using suitable mold inserts or any other suitable means. As such, the second mold half **116** can be generally thought of as a “mold core half”. Even though not depicted in FIG. 2, the first mold half **114** may be further associated with a melt distribution network, commonly known as a hot runner, for distributing molding material from the injection unit **106** to each of the one or more mold cavities **118**. The melt distribution network comprises one or more hot runner nozzle, which will be described in greater detail herein below.

[0109] Also, the second mold half **116** is provided with neck rings (not depicted) produce preforms with the neck portions **32**. The second mold half **116** is provided with the cavity origin insert for imprinting the cavity identification number **15** on the multilayer preforms **50**.

[0110] The first mold half **114** can be coupled to the fixed platen **102** by any suitable means, such as a suitable fastener (not depicted) or the like. The second mold half **116** can be coupled to the movable platen **104** by any suitable means, such as a suitable fastener (not depicted) or the like. It should be understood that in an alternative non-limiting embodiment of the present technology, the position of the first mold half **114** and the second mold half **116** can be reversed and, as such, the first mold half **114** can be associated with the movable platen **104** and the second mold half **116** can be associated with the fixed platen **102**. In an alternative non-limiting embodiment of the present technology, the fixed platen **102** need not be stationary and may be movable in relation to other components of the injection molding machine **100**.

[0111] FIG. 2 depicts the first mold half **114** and the second mold half **116** in a so-called “mold open position” where the movable platen **104** is positioned generally away from the fixed platen **102** and, accordingly, the first mold half **114** is positioned generally away from the second mold half **116**. For example, in the mold open position, a molded article (not depicted) can be removed from the first mold half **114** and/or the second mold half **116**. In a so-called “mold closed position” (not depicted), the first mold half **114** and the second mold half **116** are urged together (by means of movement of the movable platen **104** towards the fixed platen **102**) and cooperate to define (at least in part) a molding cavity (not depicted) into which the molten plastic (or other suitable molding material) can be injected, as is known to those of skill in the art.

[0112] It should be appreciated that one of the first mold half **114** and the second mold half **116** can be associated with a number of additional mold elements, such as for example, one or more leader pins (not depicted) and one or more leader bushings (not depicted), the one or more leader pins cooperating with one or more leader bushings to assist in alignment of the first mold half **114** with the second mold half **116** in the mold closed position, as is known to those of skill in the art.

[0113] The injection molding machine **100** can further comprise a robot **122** operatively coupled to the fixed platen **102**. Those skilled in the art will readily appreciate how the robot **122** can be operatively coupled to the fixed platen **102** and, as such, it will not be described here in any detail. The robot **122** comprises a mounting structure **124**, an actuating arm **126** coupled to the mounting structure **124** and a take-off plate **128** coupled to the actuating arm **126**. The take-off plate **128** comprises a plurality of molded article receptacles **130**.

[0114] Generally speaking, the purpose of the plurality of molded article receptacles **130** is to remove molded articles from the one or more mold cores **120** (or the one or more mold cavities **118**) and/or to implement post mold cooling of the molded articles. In the non-limiting example illustrated herein, the plurality of molded article receptacles **130** comprises a plurality of cooling tubes for receiving a plurality of molded preforms. However, it should be expressly understood that the plurality of molded article receptacles **130** may have other configurations. The exact number of the plurality of molded article receptacles **130** is not particularly limited.

[0115] Schematically depicted in FIG. **2** is the robot **122** of a side-entry type. However, it should be understood that in alternative non-limiting embodiments of the present technology, the robot **122** can be of a top-entry type. It should also be expressly understood that the term “robot” is meant to encompass structures that perform a single operation, as well as structures that perform multiple operations.

[0116] The injection molding machine **100** further comprises a post-mold treatment device **132** operatively coupled to the movable platen **104**. Those skilled in the art will readily appreciate how the post-mold treatment device **132** can be operatively coupled to the movable platen **104** and, as such, it will not be described here in any detail. The post-mold treatment device **132** comprises a mounting structure **134** used for coupling the post-mold treatment device **132** to the movable platen **104**. The post-mold treatment device **132** further comprises a plenum **129** coupled to the mounting structure **134**. Coupled to the plenum **129** is a plurality of treatment pins **133**. The number of treatment pins within the plurality of treatment pins **133** generally corresponds to the number of receptacles within the plurality of molded article receptacles **130**.

[0117] The injection molding machine **100** further comprises a computer-implemented apparatus **140**, also referred to herein as a controller **140**, configured to control one or more operations of the injection molding machine **100**. The controller **140** includes a human-machine interface (not separately numbered) or an HMI, for short. The HMI of the controller **140** can be implemented in any suitable interface. As an example, the HMI of the controller **140** can be implemented in a multi-functional touch screen. An example of the HMI that can be used for implementing non-limiting embodiments of the present technology is disclosed in co-owned U.S. Pat. No. 6,684,264, content of which is incorporated herein by reference, in its entirety.

[0118] Those skilled in the art will appreciate that the controller **140** may be implemented using pre-programmed hardware or firmware elements (e.g., application specific integrated circuits (ASICs), electrically erasable programmable read-only memories (EEPROMs), etc.), or other related components. In other embodiments, the functionality of the controller **140** may be achieved using a processor that has access to a code memory (not shown) which stores computer-readable program code for operation of the computing apparatus, in which case the computer-readable program code could be stored on a medium which is fixed, tangible and readable directly by the various network entities, (e.g., removable diskette, CD-ROM, ROM, fixed disk, USB drive), or the computer-readable program code could be stored remotely but transmittable to the controller **140** via a modem or other interface device (e.g., a communications adapter) connected to a network (including, without limitation, the Internet) over a transmission medium, which may be either a non-wireless medium (e.g., optical or analog communications lines) or a wireless medium (e.g., microwave, infrared or other transmission schemes) or a combination thereof.

[0119] In alternative non-limiting embodiments of the present technology, the HMI does not have to be physically attached to the controller **140**. As a matter of fact, the HMI for the controller **140** can be implemented as a separate device. In some embodiments, the HMI can be implemented as a wireless communication device (such as a smartphone, for example) that is “paired” or otherwise communicatively coupled to the controller **140**.

[0120] The controller **140** can perform several functions including, but not limited to, receiving from an operator control instructions, controlling the injection molding machine **100** based on the operator control instructions or a pre-set control sequence stored within the controller **140** or

elsewhere within the injection molding machine **100**, acquire one or more operational parameters associated with the molding system and the like.

[0121] Various non-limiting embodiments of molded articles according to the present technology will be discussed with reference to FIGS. **3A** to **11**. It should be noted that in the prior art preform **50**, the core layer **40** is continuous along the body portion of the preform **50** and circularly symmetric about the longitudinal axis, with similarly symmetric trailing and leading edges **42**, **44**. In contrast, embodiments of the molded articles, or preforms, of the present technology have core layers that have some selectively introduced asymmetry to influence blow-molding characteristics during subsequent blow-molding of the preforms, to create blow-molded articles with different structural features. Broadly speaking, embodiments of the present technology contemplate selecting a geometry of the core layer such that to affect a particular material behaviour during the processing of the preform (such as by stretch blow-molding and the like).

[0122] With reference to FIGS. **3A-3B**, a molded article **300** according to one embodiment of the present technology will be described. The molded article **300**, also referred to as a multilayer preform **300**, is produced by the injection molding machine **100** described above. It is contemplated that the multilayer preform **300** could be produced by another type of molding machine in other non-limiting embodiments in accordance with the present technology.

[0123] The multilayer preform **300** consists of a neck portion **332**, a gate portion **336** and a body portion **334** extending between the neck portion **332** and the gate portion **336**. The body portion **334** of the multilayer preform **300** is formed by three layers. A majority of the body portion **334** has an overall shape that is symmetric about an axis **310** extending longitudinally through a center of the body portion **334**, as can be seen in FIG. **3A**.

[0124] On exterior sides, the body portion **334** has an outer exterior skin layer **320** and an inner exterior skin layer **325**. The skin layers **320**, **325** can be made of various materials, including any appropriate polymer resins and thermoplastics, as will be appreciated by those skilled in the art. The body portion **334** also has a core layer **340** disposed between at least a portion of the skin layers **320**, **325**. The core layer **340** is also composed of any appropriate polymer resin or thermoplastic, but is chosen to be a different material than the skin layers **320**, **325**.

[0125] As is illustrated in the FIGS. **3A-3B**, at least a majority of the neck portion **332** is composed of the first polymeric material and is free of the second polymeric material. It is contemplated that in alternative non-limiting embodiments of the present technology, at least the majority of the neck portion **332** could be composed of the second polymeric material and be free of the first polymeric material in some implementations.

[0126] The preform **300** has a radial thickness of the core layer **340** that varies about the axis **310** to accomplish the goal of aiding in asymmetrical blow-molding and the final product created thereby (being an example of selectively controlling material behaviour during post-processing of the preform **300**). It should be noted that the thickness of the skin layers **320**, **325** varies about the axis **310**, such that the overall shape of the body portion **334** remains generally symmetric. A radial thickness **390** (see FIG. **3A**) at one point about the axis **310** is smaller than a radial thickness **391** at a point opposite the radial thickness **390**. The radial thickness of the core layer **340**, as can be seen in FIG. **3B**, has a non-symmetrical annular form about the body axis **310**.

[0127] The variance of the radial thickness of the core layer **340** about the axis **310** can be achieved by adapting a design of a hot runner nozzle that is used for producing the preform **300**. With reference to FIG. **12**, there is depicted a cross section of a hot runner nozzle **1200** that cooperates with a gate insert **1202** (the cross section being taken along an operational axis of the hot runner nozzle **1200** and the gate insert **1202**).

[0128] The hot runner nozzle **1200** comprises a nozzle body **1204**. The nozzle body **1204** comprises a first nozzle insert **1206**, a second nozzle insert **1208** and a third nozzle insert **1210**. Defined, at least partially, by the first nozzle insert **1206**, the second nozzle insert **1208**, and the third nozzle insert **1210** are nozzle flow channels for conveying molding materials.

[0129] More specifically, defined in the nozzle body **1204** is a first material main nozzle channel **1212** that receives a first material for forming the inner exterior skin layer **325** and the outer exterior skin layer **320**.

[0130] The first material main nozzle channel **1212** branches off into: (i) a first material inner channel **1214** (defined in the first nozzle insert **1206**) and (ii) a first material outer channel **1216** (defined by the second nozzle insert **1208** and the third nozzle insert **1210**).

[0131] Both the first material inner channel **1214** and the first material outer channel **1216** convey the first material, which will eventually define the inner exterior skin layer **325** and the outer exterior skin layer **320**, respectively.

[0132] Also defined between the first nozzle insert **1206** and the second nozzle insert **1208** is a second material nozzle channel **1218**. The second material nozzle channel **1218** is configured to receive a second material that will define the core layer **340**.

[0133] All of the first material inner channel **1214**, the first material outer channel **1216**, and the second material nozzle channel **1218** convey their respective molding materials (i.e. the first material and the second material) towards a gate area **1220**, defined at an interface between the hot runner nozzle **1200** and the gate insert **1202**, and eventually to a molding cavity **1222** of the mold.

[0134] The hot runner nozzle **1200** further comprises a valve stem **1224**, the valve stem **1224** being configured for controlling the flow of the molding material into the gate area **1220** and the molding cavity **1222** of the mold.

[0135] More specifically, the valve stem **1224** is under control of the controller **140**. The controller **140** causes the valve stem **1224** to reciprocate between a fully opened position as is depicted in FIG. **12** (in which all of the first material and the second material can be flowing towards the molding cavity **1222** through the gate area **1220** through the first material inner channel **1214**, the first material outer channel **1216**, and the second material nozzle channel **1218**) to a fully closed position where the valve stem **1224** obstructs the gate area **1220**, such that none of the first material and the second material is flowing towards the molding cavity **1222** through the gate area **1220** through any of the first material inner channel **1214**, the first material outer channel **1216**, and the second material nozzle channel **1218**.

[0136] In some non-limiting embodiments of the present technology, the controller **140** can control the valve stem **1224** to one or more stop positions in-between the fully open and the fully closed positions of the valve stem **1224**. In some of the embodiments of the present technology, by controlling the valve stem **1224** to one or more stop positions in-between the fully open and the fully closed positions of the valve stem **1224**, the controller **140** can control the relative volumetric flow rates of the first material and the second material during various portions of the molding cycle.

[0137] With reference to FIG. **13**, there is depicted a cross section of the hot runner nozzle **1200** taken along lines **1300** of FIG. **12**. The hot runner nozzle **1200** of FIG. **13** is configured for producing preforms with the radial thickness of the core layer **340** that does not vary about the axis **310**.

[0138] With reference to FIG. **14**, there is depicted a modified version of the hot runner nozzle **1200**, the modified version of the hot runner nozzle **1200** configured to produce the preforms with the radial thickness of the core layer **340** that varies about the axis **310**. It is noted that in the FIG. **14** illustration, the shape of the first nozzle insert **1206** is adapted to produce a cross-section shape of the flow channel that is not symmetrical about the axis **310**.

[0139] Specifically, the exterior surface of the first nozzle insert **1206** (partially defining the second material nozzle channel **1218**) has an elliptical form, where the center of the elliptical form surface is off-center from a longitudinal axis of the hot runner nozzle **1200**. It is contemplated that the surface of the first nozzle insert **1206** could have different forms.

[0140] Additionally or alternatively, the shape and/or the placement of the core layer **340** can be selectively controlled by positioning of the valve stem **1224**. With reference to FIGS. **15A** through

to **15D**, there is depicted a sequence of re-positioning of the valve stem **1224** to selectively undulate the core layer **340**.

[0141] In the FIG. **15A** illustration, the valve stem **1224** is depicted in the fully opened position, where all of the first material and the second material can be flowing towards the molding cavity **1222** through the gate area **1220** through the first material inner channel **1214**, the first material outer channel **1216**, and the second material nozzle channel **1218**). It is noted that the actual flow of the first material and the second material is controlled by the controller **140** by commanding the associated injection unit **106**.

[0142] In the FIG. **15B** illustration, the valve stem **1224** is depicted in a partially closed position, where the valve stem **1224** blocks the flow of the molding material through the first material inner channel **1214**, while allowing full flow of the respective molding material through the second material nozzle channel **1218** and through the first material outer channel **1216**. This positioning of the valve stem **1224** allows, for example, biasing the positioning of the core layer **340** towards the inner skin of the preform and/or control the thickness of the core layer **340**.

[0143] In the FIG. **15C** illustration, the valve stem **1224** is depicted in another partially closed position, where the valve stem **1224** blocks the flow of the molding material through the first material inner channel **1214** and partially throttles the flow of molding material through the second material nozzle channel **1218**, while allowing the molding material to flow through the first material outer channel **1216**. This positioning of the valve stem **1224** allows, for example, further biasing the positioning of the core layer **340** towards the inner skin of the preform and/or control the thickness of the core layer **340**.

[0144] In the FIG. **15D** illustration, the valve stem **1224** is depicted again in the fully opened position, where all of the first material and the second material can be flowing towards the molding cavity **1222** through the gate area **1220** through the first material inner channel **1214**, the first material outer channel **1216**, and the second material nozzle channel **1218**). This positioning of the valve stem **1224** allows, for example, re-positioning of the core layer **340** towards the middle of the preform and/or control the thickness of the core layer **340**.

[0145] In some embodiments, the first and second materials are chosen such that a rate of thermal crystallization of the first polymeric material is substantially less than that of the second polymeric material. In some other embodiments, the second polymeric material has a substantially higher intrinsic viscosity than the first polymeric material. Such embodiments will be discussed in more detail below with reference to FIGS. **10** and **11**.

[0146] In either of such embodiments, the different blow-molding characteristics of the two different materials of the skin layers **320**, **325** and the core layer **340**, combined with the non-uniformity of the core layer thickness, allows blow molding of the preform **300** in a selectively varied way. For example, the portion of the preform **300** where the radial thickness **391** is comparatively larger, can travel a comparatively larger path during stretch blow-molding process.

[0147] With reference to FIGS. **4A-4B**, a multilayer preform **400** according to another non-limiting embodiment of the present technology will be described. The multilayer preform **400** is produced by the injection molding machine **100** described above. It is contemplated that the multilayer preform **400** could be produced by another type of molding machine in other non-limiting embodiments in accordance with the present technology.

[0148] The multilayer preform **400** includes a body portion **434** that is formed by three layers; remaining portions of the preform **400** are substantially similar to the preform **300** described above and as such need not be repeated here.

[0149] On exterior sides, the body portion **434** has an outer exterior skin layer **420** and an inner exterior skin layer **425**. The skin layers **420**, **425** can be made of various materials, including any appropriate polymer resins and thermoplastics, as will be appreciated by those skilled in the art. The body portion **434** also includes a core layer **440** disposed between the skin layers **420**, **425**. The core layer **440** is also composed of any appropriate polymer resin or thermoplastic, but is

chosen to be a different material than the skin layers **420**, **425**.

[0150] As can be seen in the Figures, a radial thickness of the core layer **440** varies about a body axis **410**. It should be noted that the thickness of the skin layers **420**, **425** also vary about the body axis **410**, such that the overall shape of the body portion **434** remains generally rotationally symmetric. In this illustrated embodiment, while the radial thickness of the core layer **440** varies about the axis **410**, the core layer **440** has a symmetrical annular form about the body axis **410**, as can be seen in FIG. 4B.

[0151] Controlling of the shape and/or placement of the core layer **440** can be implemented similarly to that of the core layer **340**—by either of the design of the hot runner nozzle and/or controlling the valve stem **1224** of the hot runner nozzle.

[0152] The variance of the radial thickness of the core layer **440** about the axis **410** can be achieved by adapting a design of a hot runner nozzle that is used for producing the preform **400**. One non-limiting embodiment of such a hot runner nozzle design including an intermediate nozzle insert **1608** is described in more detail below with respect to FIGS. 24 and 25.

[0153] With reference to FIGS. 5A-5B, a multilayer preform **500** according to another non-limiting embodiment of the present technology will be described. The multilayer preform **500** is produced by the injection molding machine **100** described above. It is contemplated that the multilayer preform **500** could be produced by another type of molding machine in other non-limiting embodiments in accordance with the present technology.

[0154] The multilayer preform **500** includes a body portion **534** that is formed by three layers; remaining portions of the preform **500** are substantially similar to the preform **300** described above and as such need not be repeated here.

[0155] As with the preform **300**, the body portion **534** has an outer exterior skin layer **520** and an inner exterior skin layer **525**, both skin layers **520**, **525** being made of the first material. The body portion **534** also has a core layer **540** composed of a second material, chosen from a different material than the skin layers **520**, **525**. In this embodiment, the core layer **540** is a semi-annular core layer, where the radial thickness of the core layer **540** varies about a body axis **510**. The skin layers **520**, **525** are in contact for a portion of the body portion **534**, where the radial thickness of the core layer **540** goes to zero.

[0156] Controlling of the shape and/or placement of the core layer **540** can be implemented similarly to that of the core layer **340**—by either of the design of the hot runner nozzle and/or controlling the valve stem **1224** of the hot runner nozzle.

[0157] The variance of the radial thickness of the core layer **540** about the axis **510** can be achieved by adapting a design of a hot runner nozzle that is used for producing the preform **500**. One non-limiting embodiment of such a nozzle design for a hot runner **1900** is described in more detail below with respect to FIGS. 28-31.

[0158] With reference to FIGS. 6A-6C, a multilayer preform **600** according to another non-limiting embodiment of the present technology will be described. The multilayer preform **600** is produced by the injection molding machine **100** described above. It is contemplated that the multilayer preform **600** could be produced by another type of molding machine in other non-limiting embodiments in accordance with the present technology.

[0159] The multilayer preform **600** includes a body portion **634** that is formed by three layers; remaining portions of the preform **600** are substantially similar to the preform **300** described above and as such need not be repeated here.

[0160] The body portion **634** of the preform **600** includes a transition portion **635** extending between a neck portion **632** and the body portion **634**. The transition portion **635** includes a transition inner layer **625** and a transition outer layer **620** of the first polymeric material. The transition portion **635** also includes a transition core layer **640** of the second polymeric material disposed between at least a portion of the layers **620**, **625**. In the illustrated embodiment, the second polymeric material is stiffer, such that a thicker portion of the core layer **640** expands less

than a thinner portion of the core layer **640** during a same blow-molding process.

[0161] Broadly speaking the non-limiting embodiment of the preform **600** contemplates placing the second polymeric material only in the transition portion **635**. A small portion of the core layer of the body portion of the preform **600** is circumferentially varying as well, as is described in other non-limiting embodiments herein.

[0162] An example of a blow-molded product **601** made from the preform **600** is illustrated in FIG. **6C**. A transition portion **675** of the product **601** has portions that expanded less during blow-molding where the core layer **640** is thicker and expanded more where the core layer **640** is thinner.

[0163] Controlling of the shape and/or placement of the core layer **640** can be implemented similarly to that of the core layer **340**—by either of the design of the hot runner nozzle and/or controlling the valve stem **1224** of the hot runner nozzle.

[0164] With reference to FIGS. **7A-7B**, a multilayer preform **700** according to another non-limiting embodiment of the present technology will be described. The multilayer preform **700** is produced by the injection molding machine **100** described above. It is contemplated that the multilayer preform **700** could be produced by another type of molding machine in other non-limiting embodiments in accordance with the present technology.

[0165] The multilayer preform **700** includes a body portion **734** is formed by three layers; remaining portions of the preform **700** are substantially similar to the preform **300** described above and as such need not be repeated here.

[0166] As with the preform **300**, the body portion **734** has an outer exterior skin layer **720** and an inner exterior skin layer **725**, both skin layers **720**, **725** being made of the first material. The body portion **734** also has a core layer **740** composed of a second material, chosen from a different material than the skin layers **720**, **725**.

[0167] In this embodiment, the radial thickness of the core layer **740** is generally uniform about a body axis **710**. The radial thickness of the core layer **740** of the preform **700** instead varies along an axial direction defined by the axis **710**. An example of a blow-molded product **701** made from the preform **700** is illustrated in FIG. **7B**. As with the preform **600**, thicker portions of the core material expands less during blow-molding than the thinner portion. The thicker portions of the core layer **740** thus cause tighter portions on the blow-molded product **701**.

[0168] Controlling of the shape and/or placement of the core layer **740** can be implemented similarly to that of the core layer **340**—by either of the design of the hot runner nozzle and/or controlling the valve stem **1224** of the hot runner nozzle.

[0169] With reference to FIGS. **8A-8C**, a multilayer preform **800** according to another non-limiting embodiment of the present technology will be described. The multilayer preform **800** is produced by the injection molding machine **100** described above. It is contemplated that the multilayer preform **800** could be produced by another type of molding machine in other non-limiting embodiments in accordance with the present technology.

[0170] The multilayer preform **800** includes a body portion **834** is formed by three layers; remaining portions of the preform **800** are substantially similar to the preform **300** described above and as such need not be repeated here.

[0171] As with the preform **300**, the body portion **834** has an outer exterior skin layer **820** and an inner exterior skin layer **825**, both skin layers **820**, **825** being made of the first polymeric material. The body portion **834** also has a core layer **840** composed of a second material, chosen from a different material than the skin layers **820**, **825**.

[0172] The core layer **840** is an interrupted layer **840**. The interrupted layer **840** is made up of a plurality of core portions **841**; the layers **820**, **825** are in contact at places where the radial thickness of the core layer **840** decreases to zero (between the core portions **841**).

[0173] A blow-molded product **801** made from the preform **800** is illustrated in Fig. **8C**. The core portions **841** form ribbing on the blow-molded product **801**.

[0174] Controlling of the shape and/or placement of the interrupted core layer **840** can be



implemented similarly to that of the core layer **340**—by either of the design of the hot runner nozzle (by adding structure that creates the interrupted shape of the interrupted core layer **840**) and/or controlling the valve stem **1224** of the hot runner nozzle.

[0175] With reference to FIGS. **9A-9C**, a multilayer preform **900** according to another non-limiting embodiment of the present technology will be described. The multilayer preform **900** is produced by the injection molding machine **100** described above. It is contemplated that the multilayer preform **900** could be produced by another type of molding machine in other non-limiting embodiments in accordance with the present technology.

[0176] The multilayer preform **900** includes a body portion **934** is formed by three layers; remaining portions of the preform **900** are substantially similar to the preform **300** described above and as such need not be repeated here.

[0177] The body portion **934** of the preform **900** includes a transition portion **935** extending between a neck portion **932** and the body portion **934**. The transition portion **935** includes a transition inner layer **925** and a transition outer layer **920** of the first polymeric material. The transition portion **935** also includes a transition core layer **940** of the second polymeric material disposed between at least a portion of the layers **920**, **925**. The core layer **940** is an interrupted layer **940**. The interrupted layer **940** is made up of a plurality of core portions **941**; the layers **920**, **925** are in contact at places where the radial thickness of the transition core layer **940** decreases to zero (between the core portions **941**).

[0178] A blow-molded product **901** made from the preform **900** is illustrated in FIG. **9C**. The core portions **941** form ribbing on the blow-molded product **901**, similar to the blow-molded product **801**.

[0179] Controlling of the shape and/or placement of the interrupted core layer **940** can be implemented similarly to that of the core layer **340**—by either of the design of the hot runner nozzle (by adding structure that creates the interrupted shape of the interrupted core layer **940**) and/or controlling the valve stem **1224** of the hot runner nozzle.

[0180] With reference to FIG. **10**, a molded article **1000** according to another non-limiting embodiment of the present technology will be described. The molded article **1000**, also referred to as a multilayer preform **1000**, is produced by the injection molding machine **100** described above. It is contemplated that the multilayer preform **1000** could be produced by another type of molding machine in other non-limiting embodiments in accordance with the present technology.

[0181] The preform **1000** includes a neck portion **1032**, a body portion **1034**, and a gate portion **1036** as described with respect to preform **50**. The body portion **1034** includes skin layers **1020** and **1025**, and a core layer **1040**. While the core layer **1040** is illustrated as the rotationally symmetric core form of the preform **50**, it is contemplated that the core layer **1040** could be implemented in the form of any of FIGS. **3A-9A**.

[0182] The inner exterior layer **1020** and the outer exterior layer **1025** are both formed from a first polymeric material, which is a non-strain hardening material. The material of the skin layers **1020**, **1025** could be chosen from, but it not limited to, high-density polyethylene (HDPE) and polypropylene (PP).

[0183] The core layer **1040** is formed from a second, different polymeric material. In this embodiment, the first and second materials are chosen such that a rate of thermal crystallization of the first polymeric material is substantially less than that of the second polymeric material. Specifically, the core layer **1020** is made of a strain-hardening material, which could include, but is not limited to, a strain-crystallizable homopolymer, copolymer, and blend of polyethylene terephthalate (PET). By including a strain-hardening material as the core layer **1040**, the preform **1000** can utilize non-strain-hardening materials, which may have preferable aesthetic and cost properties, while the strain-hardening core layer **1040** provides strength lacking in the skin layers **1020**, **1025**.

[0184] In this non-limiting embodiment, the neck portion **1032** is also made of the non-strain

hardening material, although in some non-limiting embodiments it is contemplated that the neck portion **1032** could be made from the same material as the core layer **1040**, or even a third, different material.

[0185] Controlling of the shape and/or placement of the core layer **1040** can be implemented similarly to that of the core layer **340**—by either of the design of the hot runner nozzle and/or controlling the valve stem **1224** of the hot runner nozzle.

[0186] With reference to FIG. **11**, a molded article **1100** according to another non-limiting embodiment of the present technology will be described. The multilayer preform **1100** is produced by the injection molding machine **100** described above. It is contemplated that the multilayer preform **1100** could be produced by another type of molding machine in other non-limiting embodiments in accordance with the present technology.

[0187] The preform **1100** includes a neck portion **1132**, a body portion **1134**, and a gate portion **1136** as described with respect to preform **50**. The body portion **1134** includes skin layers **1120** and **1125**, and a core layer **1140**. While the core layer **1140** is illustrated as the rotationally symmetric core form of the preform **50**, it is contemplated that the core layer **1140** could be implemented in the form of any of FIGS. **3A-9A**.

[0188] The inner exterior layer **1120** and the outer exterior layer **1125** are both formed from a first polymeric material. The core layer **1140** is formed from a second, different polymeric material. In this embodiment, the first and second materials are chosen such that the second polymeric material has a substantially higher intrinsic viscosity than the first polymeric material. In some non-limiting embodiments, the first polymeric material can be PET and the second polymeric material can be chosen from, but is not limited to, PP, polyethylene (PE), HDPE, and Nylon.

[0189] In this non-limiting embodiment, the neck portion **1132** is made from the lower viscosity material, although in some non-limiting embodiments it is contemplated that the neck portion **1032** could be made from the same material as the core layer **1140**, or even a third, different material.

[0190] Controlling of the shape and/or placement of the core layer **1140** can be implemented similarly to that of the core layer **340**—by either of the design of the hot runner nozzle and/or controlling the valve stem **1224** of the hot runner nozzle.

[0191] With reference to FIGS. **16A-16D**, a molded article **1300** according to yet another non-limiting embodiment of the present technology will be described. The molded article **1300**, specifically a multilayer preform **1300**, is produced by the injection molding machine **100** described above, using a hot runner nozzle **1400** illustrated in FIGS. **17-18** (described in more detail below). It is contemplated that the multilayer preform **1300** could be produced by another type of molding machine in other non-limiting embodiments in accordance with the present technology.

[0192] The preform **1300** includes a neck portion (not shown), a body portion **1334**, and a gate portion **1336** as described with respect to preform **50**. The body portion **1334** includes skin layers **1320** and **1325**, and a core layer **1340**. The inner exterior layer **1320** and the outer exterior layer **1325** are both formed from a first polymeric material, also referred to as the skin layer material. The material of the skin layers **1320**, **1325** could be chosen from, but it not limited to, high-density polyethylene (HDPE) and polypropylene (PP).

[0193] The core layer **1340** is formed from a second, different polymeric material, also referred to as the core layer material. In this embodiment, the second polymeric material is a different color than the first polymeric material, but the second polymeric material can be selected with any desired material type, material characteristic, material quality, material type (i.e. virgin or regrind), and the like. As can be seen in the image of an experimentally produced preform **1300** shown in FIG. **16C**, the core layer **1320** is made of a purple colored material, while the first polymeric material is a generally translucent material. In some embodiments, rather than being without color, the first polymeric material could be a different color than the second polymeric material. Both the first and second polymeric materials could be made from, but are not limited to, a homopolymer,

copolymer, and blend of polyethylene terephthalate (PET). It is contemplated that different polymeric materials, which may have different physical, aesthetic and/or cost properties, could be used for the core layer **1340** and/or the skin layers **1320**, **1325**.

[0194] The core layer **1340** includes localized regions of increased radial thickness (see FIGS. **16A**, **16B**). Due to the increased radial thickness of the purple core layer, the purple color is more present and the preform **1300** (and its eventual final-shaped container) is differently colored in the localized regions of greater thickness. Specifically, in the illustrated embodiment the core layer includes two wider localized regions **1342** and two narrower localized regions **1344**. In corresponding regions of the outer skin layer **1320**, the outer skin layer **1320** also has localized regions of thinner material. The purple material core layer **1340**, due to the localized regions of thicker core layer **1340** and thinner skin layer **1320** about a longitudinal axis of the preform **1300** creates four longitudinally-extending stripes in the preform **1300** that can be seen from an exterior of the preform **1300**. It should be noted that in alternative non-limiting embodiments of the present technology, there could be more or fewer ones of the localized regions of thicker core layer **1340** and thinner skin layer **1320**. By the same token, all of the localized regions of thicker core layer **1340** and thinner skin layer **1320** could be of the same dimension-either smaller or larger.

[0195] In some other non-limiting embodiments of the preform **1300**, the core layer **1340** could include strain-hardening materials or materials of different viscosity, such as described above for other embodiments of preforms according to this technology. In such an embodiment, stretching and blow-molding of the preform into the final shaped container could be at least partially governed by the different thickness of the localized regions of the core layer **1340**.

[0196] With reference to FIGS. **17** and **18**, the hot runner nozzle **1400** used to create the preform **1300** will now be described in more detail. While the use of the hot runner nozzle **1400** will be described with respect to formation of the preform **1300**, it is also contemplated that the hot runner nozzle **1400** could be used to create different embodiments of molded articles and multilayer preforms.

[0197] The hot runner nozzle **1400** comprises an inner nozzle insert **1406** (also referred to as a first nozzle insert **1406**), an intermediate nozzle insert **1408** (also referred to as a second nozzle insert **1408**), and an outer nozzle insert **1410** (also referred to as a third nozzle insert **1410**). The inner nozzle insert **1406** defines an inner flow channel **1414** therein. The inner nozzle insert **1406** and the intermediate nozzle insert **1408** define an intermediate flow channel **1418** therebetween. The intermediate nozzle insert **1408** and the outer nozzle insert **1410** define an outer flow channel **1416** therebetween. Although not specifically illustrated, the hot runner nozzle **1400** further cooperates with a valve stem (not shown), similarly to the nozzle **1200** and the valve stem **1224** described above. The hot runner nozzle **1400** defines a longitudinal axis **1402**, which is generally an operational axis of the nozzle **1400**.

[0198] Both the inner flow channel **1414** and the outer flow channel **1416** convey the first polymeric material, which will eventually define for the preform **1300** the inner exterior skin layer **1325** and the outer exterior skin layer **1320**, respectively. The intermediate flow channel **1418** is configured to receive the second polymeric material that will define the core layer **1340**. The intermediate nozzle insert **1408** and the inner nozzle insert **1406** further cooperate to define an intermediate outlet **1420** of the intermediate flow channel **1418**, where a majority of the second polymeric material flows through when the hot runner nozzle **1400** is in use.

[0199] The intermediate nozzle insert **1408** further defines four apertures disposed upstream and spaced from the intermediate outlet **1420**. Specifically, the intermediate nozzle insert **1408** has two apertures **1433**, separated by 180 degrees around the axis **1402**, and two apertures **1435** disposed between and equidistant from each of the apertures **1433**. The apertures **1433**, **1435** are arranged to provide a fluid connection between the intermediate flow channel **1418** and the outer flow channel **1416**.

[0200] As the intermediate flow channel **1418** is fluidly connected to the outer flow channel **1416**

upstream of the intermediate outlet **1420**, via the apertures **1433**, **1435**, the distribution of core layer material versus outer skin layer material is modified in localized regions downstream from the apertures **1433**, **1435**. When in use, at least a portion of the second polymeric material (i.e. the core layer material) melt flow passing through the intermediate flow channel **1418** passes through the apertures **1433**, **1435** into the outer flow channel **1416**.

[0201] The core layer material passing through the apertures **1433**, **1435** then forms the localized regions of increased radial thickness **1342**, **1344** illustrated in FIGS. **16A-D**. The portion of the core layer material passing from the intermediate flow channel **1418** and into the outer flow channel **1416** generally join together again in the preform **1300**, where those separated streams of the core layer material form a core layer **1340** of greater thickness at that point. In so doing, a portion of the core layer material also displaces a portion of the skin layer material in the outer flow channel **1416**, as can be seen in the Figures, in localized regions corresponding to the locations of the apertures **1433**, **1435**. As can be seen in cross-section, the larger apertures **1433** allow through more core layer material than the smaller apertures **1435**, leading to greater increase in the radial thickness of the core layer **1340**.

[0202] It is contemplated that the intermediate nozzle insert **1408** could define more or fewer apertures **1433**, **1435**, depending on the specific implementation or application. Some such variations are explored in following portions of the description. Similarly, placement, size, and orientation of the apertures **1433**, **1435** could vary, as will be explored in further embodiments of hot runner nozzles and nozzle inserts.

[0203] With reference to FIGS. **19** to **21**, another non-limiting embodiment of a hot runner nozzle design, specifically including an intermediate nozzle insert **1508**, for producing at least some of the preform designs presented above, will now be described. While not illustrated explicitly, the intermediate nozzle insert **1508** can be used in the hot runner nozzle **1400** in place of the intermediate nozzle insert **1408**.

[0204] In this non-limiting embodiment, the intermediate nozzle insert **1508** includes a total of 20 apertures for fluidly connecting the intermediate flow channel to the outer flow channel. The intermediate nozzle insert **1508** defines four circular, horizontally arranged apertures **1530** disposed along each of four longitudinally extending lines, each line of apertures **1530** being equidistant, around the operational axis, from its neighboring line. The intermediate nozzle insert **1508** further defines four smaller circular apertures **1532** disposed about the bottom portion of the intermediate nozzle insert **1508**.

[0205] By controlling flow rates, it is also contemplated that the extent of core layer radial thickness variation could be managed. For example, by varying flow rate through a particular cycle, addition variation in the localized core layer radial thickness along the longitudinal direction could be produced.

[0206] With reference to FIGS. **22** and **23**, another non-limiting embodiment of a hot runner nozzle design, specifically an intermediate nozzle insert **1558**, for producing at least some of the preform designs presented above, will now be described. While not illustrated explicitly, the intermediate nozzle insert **1558** can be used in the hot runner nozzle **1400** in place of the intermediate nozzle insert **1408**.

[0207] In the non-limiting embodiment of the intermediate nozzle insert **1558**, hot runner nozzle includes a total of 20 apertures for fluidly connecting the intermediate flow channel to the outer flow channel. The intermediate nozzle insert **1508** defines four circular apertures **1580** disposed along each of four longitudinally extending lines, each line of apertures **1530** being equidistant, around the operational axis, from its neighboring line. The apertures **1580** are arranged at various angles, the apertures **1580** generally being oriented at a greater angle to horizontal lower down the operational axis. The intermediate nozzle insert **1558** further defines four smaller circular apertures **1582** disposed about the bottom portion of the intermediate nozzle insert **1558**, similarly to the intermediate nozzle insert **1508**.

[0208] As can be seen in this non-limiting embodiment, the apertures **1580** need not all be arranged at a same angle with respect to the operational axis. The apertures **1580** further need not be equally spaced, as can be seen from at least the top two apertures **1580** along each longitudinal line. It is contemplated that the intermediate nozzle insert **1558** could include more or fewer apertures, depending on the specific embodiment.

[0209] With reference to FIGS. **24** and **25**, another non-limiting embodiment of a hot runner nozzle design, specifically an intermediate nozzle insert **1608**, for producing at least some of the preform designs presented above, including at least the preform **400** illustrated in FIGS. **4A** and **4B**, will now be described in more detail.

[0210] In the non-limiting embodiment of the intermediate nozzle insert **1608**, hot runner nozzle includes two apertures **1630**. Each aperture **1630** is in the form of a curved slot, which allows core layer material to pass from the intermediate flow channel into an interior side of the outer flow channel. The resulting core layer, as is illustrated in FIGS. **4A** and **4B**, is slightly thickened along a wide portion of the core layer circumference.

[0211] In some embodiments, the apertures **1630** could be larger or smaller than illustrated. It is also contemplated that the intermediate nozzle insert **1608** could include additional apertures, either in the form of the apertures **1630** or in a different form. It is also contemplated that for some embodiments, the apertures **1630** could be defined in an inner nozzle insert rather than the intermediate nozzle insert **1608**.

[0212] With reference to FIG. **26**, an illustrative example of a hot runner nozzle **1700** for producing at least some of the preform designs presented above will now be described.

[0213] The hot runner nozzle **1700** comprises an inner nozzle insert **1706** (also referred to as a first nozzle insert **1706**), an intermediate nozzle insert **1708** (also referred to as a second nozzle insert **1708**), and an outer nozzle insert **1710** (also referred to as a third nozzle insert **1710**). The inner nozzle insert **1706** defines an inner flow channel **1714** therein. The inner nozzle insert **1706** and the intermediate nozzle insert **1708** define an intermediate flow channel **1718** therebetween. The intermediate nozzle insert **1708** and the outer nozzle insert **1710** define an outer flow channel **1716** therebetween.

[0214] Although not specifically illustrated, the hot runner nozzle **1700** further cooperates with a valve stem (not shown), similarly to the nozzle **1200** and the valve stem **1224** described above. The hot runner nozzle **1700** defines a longitudinal axis **1702**, which is generally an operational axis of the nozzle **1700**.

[0215] Both the inner flow channel **1714** and the outer flow channel **1716** convey the first polymeric material, which will eventually define an inner exterior skin layer and an outer exterior skin, respectively, of a molded article produced by the hot runner nozzle **1700**. The intermediate flow channel **1718** is configured to receive the second polymeric material that will define the core layer of the molded article.

[0216] The inner nozzle insert **1706** further defines four apertures disposed upstream and spaced from an outlet of the inner nozzle insert **1706**. Specifically, the inner nozzle insert **1706** has four apertures **1730**. The apertures **1730** are arranged to fluidly connect the inner flow channel **1714** to the intermediate flow channel **1718**.

[0217] Similarly to the above described hot runner nozzles, the hot runner nozzle **1700** produces, when in use, molded articles that have core layers with localized regions of modified radial thickness. In this embodiment, a portion of the material flowing through the inner flow channel **1714** will divert into the intermediate flow channel **1718**, displacing a portion of the core layer material. This causes localized regions of decreased radial thickness of the core layer. It is contemplated that the inner nozzle insert **1706** could define more or fewer apertures **1730** therein.

[0218] With reference to FIG. **27**, an illustrative example of an intermediate nozzle insert **1800** with different, non-limiting embodiments of apertures. While illustrated on the intermediate nozzle insert **1800**, it is also contemplated that each of the example apertures could be implemented with

an inner nozzle insert, such as in the non-limiting embodiment of the hot runner nozzle **1700**.

[0219] As is described with respect to at least the nozzle inserts **1408**, **1508**, **1558**, **1608**, and **1706**, the apertures as developed in the present technology, upstream and off-set from the material main outlets, allow a portion of the core layer material to pass from the intermediate flow channel into either the inner flow channel or the outer flow channel. In so doing, the molded articles produced have a core layer with localized regions of increased radial thickness. Further, a portion of the core layer material can displace a portion of the skin layer material about the localized regions.

[0220] Depending on various factors, the apertures used can be of different forms. These factors could include, but are not limited to: properties of the particular materials being used in the skin layers, the core layer, or both; different cycle parameters of the nozzle when in use; and the desired amount of variation in the core layer radial thickness.

[0221] In some embodiments, the apertures can be generally cylindrical and angled, such as apertures **1802** and **1804**. In some embodiments, the apertures can be generally cylindrical and generally parallel to the operational axis, such as the aperture **1806**. Depending on specifics of the embodiment, the apertures could be curved, such as the aperture **1808**. In some embodiments, the apertures can expand to be larger as the aperture extends away from the intermediate flow channel, such as the aperture **1810** (with generally linear walls) or the aperture **1812** (with curved walls). Similarly, in some embodiments the apertures can get narrower as they extend away from the intermediate flow channel, such as the aperture **1814** (with generally linear walls) or the aperture **1816** (with curved walls).

[0222] Choice of one or more of the above apertures **1802-1816** could depend on various factors, including the extent to which the core layer is meant to be modified, for instance, or if the core layer material crossing into the outer flow channel is meant to penetrate through the outer skin layer or to be nearer the surface of the preform produced. It is also contemplated that the apertures could be further varied, for example by having larger or smaller diameters than those illustrated. The relative spacing, orientation, and location of different apertures could further vary, depending on the particular embodiment. During use, it is also contemplated that any of stem position, injection speed, and injection timing, among other process variables, could be controlled to create different effects on the preform produced. It should be noted that various methods could be utilized to create the apertures, including, for example, electrical discharge machining and 3D printing of the nozzle inserts, but fabrication of the present technology is not meant to be so limited.

[0223] These are non-limiting examples of different apertures that could be defined in at least one of the intermediate nozzle insert and the inner nozzle insert, but still further different forms could be implemented. Depending on the embodiment, one or both of the intermediate and inner nozzle inserts could include as few as one aperture up to many apertures. It is also contemplated that in some embodiments, multiple versions of the apertures **1802-1816** (or other forms) could be implemented in a single embodiment.

[0224] Additionally, the shape and/or the placement of the core layer of preforms produced using the hot runner nozzles or inserts **1400**, **1508**, **1558**, **1608**, **1700**, or **1800** could be selectively controlled by positioning of the valve stem **1224**, as is described above.

[0225] With reference to FIGS. **28** to **31**, another non-limiting embodiment of a hot runner nozzle **1900**, specifically an inner nozzle insert **1906**, for producing at least some of the preform designs presented above, will now be described.

[0226] The hot runner nozzle **1900** comprises an inner nozzle insert **1906**, an intermediate nozzle insert **1908**, and an outer nozzle insert **1910**. The inner nozzle insert **1906** defines an inner flow channel **1914** therein, the inner flow channel **1914** including an outlet **1922**. The inner nozzle insert **1906** and the intermediate nozzle insert **1908** define an intermediate flow channel **1918** therebetween. The intermediate nozzle insert **1908** and the outer nozzle insert **1910** define an outer flow channel **1916** therebetween. The inner nozzle insert **1906** and the intermediate nozzle insert **1908** further cooperate to define an intermediate outlet **1920** through which at least the core layer

material passes. The outer nozzle insert **1910** further defines an outlet **1924** through which at least the outer exterior skin layer material passes. The hot runner nozzle **1900** also defines a longitudinal axis **1902**, which is generally an operational axis of the nozzle **1900**.

[0227] As can be seen from the Figures, the inner nozzle insert **1906** is formed such that the intermediate outlet **1920** has a non-uniform cross-section. As the core layer material passes out of the hot runner nozzle **1900**, when in use, through the non-uniform intermediate outlet **1920**, a molded article created using the hot runner nozzle **1900** would have a core layer having a non-uniform radial thickness about the axis **1902**. As one non-limiting example, the preform **500** illustrated in FIGS. 5A and 5B could be created using the hot runner nozzle **1900**. The core layer **540** of the preform **500** extends only partially around a circumference of the preform **500**, corresponding to the partial intermediate flow channel **1918**.

[0228] As can be seen in the Figures, the intermediate outlet **1920**, and the outer outlet **1924** are immediately adjacent to one another. Specifically, the inner outlet **1922** and the outer outlet **1924** are arranged concentrically. Due to the form of the inner nozzle insert **1906**, as will be discussed in more detail below, the intermediate outlet **1920** extends only partially around the axis **1902** of the hot runner nozzle **1900** and is disposed between only a portion of the concentrically arranged inner and outer outlets **1922**, **1924**.

[0229] The inner nozzle insert **1906** has two general surface forms, as can be seen in FIGS. 28 and 29. The first surface form **1940** matches the form of an interior surface of the intermediate nozzle insert **1908**. The second surface form **1942**, when the inner nozzle insert **1906** is arranged in the hot runner nozzle **1900**, is spaced from the interior surface of the intermediate nozzle insert **1908** to define the intermediate flow channel **1918**. In the region of the surface form **1940**, there is no core layer material flow, as the inner nozzle insert **1906** is in contact with the intermediate nozzle insert **1908**. As such, as can be seen in preform **500**, the core layer **540** only extends around a portion of the circumference of the preform **500**.

[0230] In some non-limiting embodiments, it is contemplated that portions of the channels **1916**, **1918** could be modified to compensate for an imbalance of flows in the channels **1916**, **1918** due to their non-uniform nature. For example, in some embodiments the outer flow channel **1916** could be thinner in portions about the axis where the intermediate flow channel **1918** is defined, such that the total flow from the channels **1916**, **1918** has a total flow volume that is similar or the same as portion of the nozzle **1900** where there is no intermediate flow channel **1918** defined, and all flow is coming only from the outer flow channel **1916**. It is also contemplated that the form of the channels **1916**, **1918** could be modified to balance pressure through the nozzle **1900**, during use.

[0231] Broadly speaking the non-limiting embodiments of hot runner nozzles and nozzle inserts for conveying melt to a mold cavity described above are designed to deliver core layer material such that the molded articles produced in the mold cavity have a non-uniform radial thickness about a longitudinal axis of the molded article. Specifically, flow of material through the intermediate flow channel, when the hot runner nozzle is in use, is non-uniformly distributed about a longitudinal axis of the hot runner nozzle. The non-uniformity of the flow is generally attributable to surfaces of the intermediate nozzle insert and the inner nozzle which define the intermediate flow channel. In some of the above described embodiments of the present technology, the surfaces define apertures through which the core layer material passes to create localized increased core layer thickness. In other embodiments of the present technology, the surfaces form intermediate flow channels that do not extend uniformly about the hot runner nozzle axis, such that the core layer material is not uniformly distributed about the molded article.

[0232] It should be noted that even though the core layer depicted in the various embodiments of the present technology is not fully encapsulated in the gate portion of the preform (i.e. it is interrupted in the gate portion of the preform), in alternative non-limiting embodiments of at least those preforms depicted in FIGS. 3A, 4A, 8A, 10, 11, and 16A-D; the respective core layers can be fully encapsulated (i.e. be continuous) in the gate portions of the preforms.

[0233] The polymeric material used to form any of the foregoing non-limiting embodiments of multi-layer articles **300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1300** can be chosen where one polymeric material is of a first color and the other polymeric material is of a second color in order to create a variation in color distribution in the final-shaped container, where color variation is governed by the selectively varied radial thickness of the core layer.

[0234] The polymeric material used to form the foregoing non-limiting embodiments of multi-layer articles **300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1300** may be selected or otherwise modified to resist layer delamination. Where two adjacent layers are formed from polymeric materials that are prone to delamination a bonding agent may be employed to improve the bond therebetween. Related teachings on the provision of bonding agents is provided, for example, with reference to US patent application, US 2011/0262668, assigned to Graham Packaging Company L.P., incorporated by reference herein, and a journal article entitled 'Compatibilizer Additives for Improving the Delamination Resistance of PET/Pa-MXD6 Multilayer Coinjection Stretch Blow Molded Bottles' authored by Kris Akkapeddi and Brian Lynch of Graham Packaging Co., York, PA, U.S.A. and published by the Society of Plastics Engineers Bethel, CT, U.S.A., In the non-limiting example of a PET and HDPE interface a bonding agent such as, for example, Surlyn® (trademark of E. I. du Pont de Nemours and Company of Wilmington, Delaware, U.S.A.), Orevac® (trademark of Arkema S.A. of Colombes, France), or Aclyn® (trademark of Honeywell International Inc. of Morris Plains, New Jersey, U.S.A.) may be provided.

[0235] Modifications and improvements to the above-described embodiments of the present technology may become apparent to those skilled in the art. The foregoing description is intended to be exemplary rather than limiting. The scope of the present technology is therefore intended to be limited solely by the scope of the appended claims.

[0236] The description of the embodiments of the present technology provides only examples of the present technology, and these examples do not limit the scope of the present technology. It is to be expressly understood that the scope of the present technology is limited by the claims only. The concepts described above may be adapted for specific conditions and/or functions, and may be further extended to a variety of other applications that are within the scope of the present technology. Having thus described the embodiments of the present technology, it will be apparent that modifications and enhancements are possible without departing from the concepts as described.

## Claims

**1.-8.** (canceled)

**9.** A hot runner nozzle for conveying melt to a mold cavity, the hot runner nozzle comprising: an inner nozzle insert defining an inner flow channel, the inner flow channel including an inner outlet; an intermediate nozzle insert disposed around the inner nozzle insert, the intermediate nozzle insert and the inner nozzle insert defining an intermediate flow channel, the intermediate flow channel including an intermediate outlet; and an outer nozzle insert disposed around the intermediate nozzle insert, the outer nozzle insert and the intermediate nozzle insert defining an outer flow channel, the outer flow channel including an outer outlet, the inner nozzle insert being formed such that the intermediate outlet has a non-uniform cross-section.

**10.** The hot runner nozzle of claim 9, wherein the mold cavity is for defining, in use, a molded article having a core layer and a skin layer surrounding the core layer, the core layer being formed from material flowing through the intermediate flow channel, the material having a non-uniform radial thickness about the axis.

**11.** The hot runner nozzle of claim 9, wherein the inner outlet, the intermediate outlet, and the outer outlet are immediately adjacent to one another.

**12.** The hot runner nozzle of claim 9, wherein the inner nozzle insert is formed such that the



intermediate outlet extends only partially around a longitudinal axis of the hot runner nozzle.

**13.** The hot runner nozzle of claim 9, wherein: the inner nozzle insert has an exterior surface partially defining the intermediate flow channel; and the exterior surface has an elliptical form, a center of the elliptical form surface being off-center from a longitudinal axis of the hot runner nozzle.

**14.** The hot runner nozzle of claim 9, wherein the inner outlet and the outer outlet are arranged concentrically.

**15.** The hot runner nozzle of claim 14, wherein the intermediate outlet is disposed between a portion of the concentrically arranged inner and outer outlets.

**16.** The hot runner nozzle of claim 9, wherein, in use, when transferring the melt to the mold cavity: a first stream of melt of a first polymeric material flows through and exits the inner flow channel and the outer flow channel; a second stream of melt of a second polymeric material flows through and exits the intermediate flow channel, the second polymeric material forming a core layer of a molded product produced by the melt in the mold cavity; and the first stream of melt and the second stream of melt intersect at a combination area.

**17.** The hot runner nozzle of claim 9, wherein the mold cavity is for defining, in use, a molded article having a core layer and a skin layer surrounding the core layer, the core layer being formed from the second polymeric material flowing through the intermediate flow channel, the core layer having a non-uniform radial thickness about a longitudinal axis of the molded article.

**18.** A hot runner nozzle for conveying melt to a mold cavity, the hot runner nozzle comprising: an inner nozzle insert defining an inner flow channel; an intermediate nozzle insert disposed around the inner nozzle insert, the intermediate nozzle insert and the inner nozzle insert defining an intermediate flow channel; and an outer nozzle insert disposed around the intermediate nozzle insert, the outer nozzle insert and the intermediate nozzle insert defining an outer flow channel, flow of material through the intermediate flow channel, when the hot runner nozzle is in use, being non-uniformly distributed about a longitudinal axis of the hot runner nozzle, the non-uniformity of the flow being attributable to surfaces of the intermediate nozzle insert and the inner nozzle which define the intermediate flow channel, the mold cavity being for defining, in use, a molded article having a core layer and a skin layer surrounding the core layer, the core layer formed from material flowing through the intermediate flow channel, the core layer having a non-uniform radial thickness about a longitudinal axis of the molded article.

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