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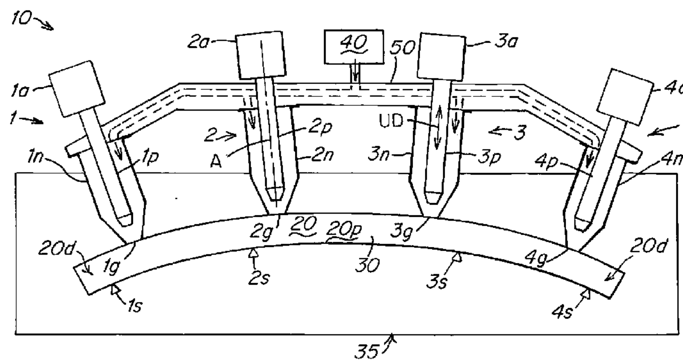
(54) **Title**: ADJUSTED CAVITY INJECTION FLUID PRESSURES IN INJECTION MOLDING SYSTEMS

(57) **Abstract**: An injection molding system (10) and method of use where the system (10) is comprised of an injection molding machine (40), a heated manifold (50), a plurality of nozzles (1 n, 2n, 3n, 4n) each having a respective gate (1 g, 2g, 3g, 4g) communicating with one or more cavities (20), each nozzle having a valve comprised of an actuator (1 a, 2a, 3a, 4a) and a corresponding valve pin (1 p, 2p, 3p, 4p), wherein the method establishes pack or fill pressures comprising: injecting injection fluid (1153) on a first injection cycle, forming a first one or more parts or objects, inspecting or measuring the first one or more parts or objects, determining an updated pack or fill pressure, injecting injection fluid (1153) on a successive injection cycle where the pack and fill pressures are adjusted to match the updated pack or fill pressures.



	NOZZLE			
	1n	2n	3n	4n
Cycle 1				
Fill Pressure	1000	1000	1000	1000
Pack Pressure	700	1000	1000	500
Cycle 2				
Fill Pressure	700	850	850	700
Pack Pressure	1600	500	500	1600

Fig. 1

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ADJUSTED CAVITY INJECTION FLUID PRESSURES IN INJECTION MOLDING SYSTEM

RELATED APPLICATIONS

[001] This application claims the benefit of priority to U.S. Provisional Application serial no. 62/265,098 filed December 9, 2015, the disclosure of which is incorporated by reference in its entirety as if fully set forth herein.

[002] This application is a continuation-in-part of and claims the benefit of priority to U.S. Application Serial No. 14/243,277 filed April 2, 2014, the disclosure of which is incorporated by reference as if fully set forth in its entirety herein.

[003] The disclosures of all of the following are incorporated by reference in their entirety as if fully set forth herein: U.S. Patent No. 5,894,025, U.S. Patent No. 6,062,840, U.S. Patent No. 6,294,122, U.S. Patent No. 6,309,208, U.S. Patent No. 6,287,107, U.S. Patent No. 6,343,921, U.S. Patent No. 6,343,922, U.S. Patent No. 6,254,377, U.S. Patent No. 6,261,075, U.S. Patent No. 6,361,300 (7006), U.S. Patent No. 6,419,870, U.S. Patent No. 6,464,909 (7031), U.S. Patent No. 6,599,116, U.S. Patent No. 7,234,929 (7075US1), U.S. Patent No. 7,419,625 (7075US2), U.S. Patent No. 7,569,169 (7075US3), U.S. Patent Application Serial No. 10/214,118, filed August 8, 2002 (7006), U.S. Patent No. 7,029,268 (7077US1), U.S. Patent No. 7,270,537 (7077US2), U.S. Patent No. 7,597,828 (7077US3), U.S. Patent Application Serial No. 09/699,856 filed October 30, 2000 (7056), U.S. Patent Application Serial No. 10/269,927 filed October 11, 2002 (7031), U.S. Application Serial No. 09/503,832 filed February, 15, 2000 (7053), U.S. Application Serial No. 09/656,846 filed September 7, 2000 (7060), U.S. Application Serial No. 10/006,504 filed December 3, 2001, (7068) and U.S. Application Serial No. 10/101,278 filed March, 19, 2002 (7070) and PCT application no. PCT/US2011/029721 filed March 24, 2011 (7094), PCT publication no. WO2012074879 (A1) (7100WO0) and WO2012087491 (A1) (7100W01) and PCT/US2013/75064 (7129WO0) and PCT/US2014/19210 (7129WO1) and PCT/US2014/31000 (7129WO2).

BACKGROUND OF THE INVENTION

[004] Injection molding systems that control pin position during the course of an injection cycle have been developed where the position of the pin is dynamically controlled in a closed loop in real time to follow a predetermined profile of pin positions based on a comparison of the pin position with a predetermined profile of pin positions. In systems where multiple nozzles are used to simultaneously inject fluid material to either multiple separate cavities or into a single cavity, prior systems rely on a single predetermined set of pin position data to control the rate of flow of injection fluid material into each separate cavity or otherwise through each separate gate leading to a single cavity.

SUMMARY OF THE INVENTION

[005] In accordance with the invention there is provided in an injection molding system (10) comprised of an injection molding machine (40), a heated manifold (50) into which the injection molding machine injects a selected injection fluid (1153), a plurality of nozzles (1n, 2n, 3n, 4n) receiving injection fluid (1153) from the heated manifold (50), the nozzles each having a respective gate (1g, 2g, 3g, 4g) communicating with one or more cavities (20), each nozzle having a valve comprised of an actuator (1a, 2a, 3a, 4a) and a corresponding valve pin (1p, 2p, 3p, 4p) controllably driven by the actuator to control velocity or pressure of injection fluid flow (1153) through the gates of the nozzles during an injection cycle having a selected duration, the injection cycle comprising a fill phase wherein between about 90% and about 99% of the mold cavity is filled with injection fluid and a subsequent pack phase wherein between about 1% and about 10% of the mold cavity is filled with injection fluid,

a method for establishing pack or fill pressures of the injection fluid injected during the pack and fill phases at preselected positions within the cavity (20) of the mold (35), the method comprising:

injecting injection fluid (1153) on a first injection cycle through each of the gates (1g, 2g, 3g, 4g) of each of the nozzles (1n, 2n, 3n, 4n) and recording one or both of the pack and fill pressures at each of the selected positions within the one or more mold cavities,

forming a first one or more parts or objects within a corresponding one or more mold cavities (20) during the first injection cycle,

inspecting or measuring the first one or more parts or objects,

determining an updated pack or fill pressure for each of the selected positions within the one or more mold cavities based on the inspecting or measuring,

injecting injection fluid (1153) on a successive injection cycle through each of the gates and controlling the actuators (1a, 2a, 3a, 4a) corresponding to each gate

(1g, 2g, 3g, 4g) to adjust positioning of the valve pins (1p, 2p, 3p, 4p) such that pressure or velocity of flow of injection fluid through the gates is adjusted to match the pack or fill pressure for each of the selected positions within the one or more mold cavities (20) to the updated pack or fill pressures.

[006] In such a method the actuators, valve pins and gates are typically adapted such that the valve pins are controllably drivable between a gate closed position at which injection fluid flow is stopped and pressure is zero at the gate, a fully upstream gate open position at which injection fluid flow is at a maximum velocity and pressure and one or more intermediate upstream positions between the gate closed and fully upstream gate open position at which injection fluid flow pressure and velocity is at a reduced between zero and the maximum,

the pressure or velocity of injection fluid flow through the gates being adjusted during one or more of the successive injection cycles by controlling positioning of a distal end of one or more valve pins relative to an interior surface of a corresponding gate to controllably reduce velocity of flow of the injection fluid to one or more reduced velocities between zero and the maximum velocity.

[007] One or more of the valve pins is typically withdrawn and maintained in at least one selected intermediate upstream position for a selected portion or all of the duration of the injection cycle.

[008] Most typically one or more of the valve pins is withdrawn and maintained in at least one selected intermediate upstream position for a selected portion or all of the fill and pack phases of the injection cycle.

[009] In another aspect of the invention there is provided an apparatus for adjusting the rate of injection fluid flow comprising an injection molding system (10) comprised of an injection molding machine (40), a heated manifold (50) into which the injection molding machine injects a selected injection fluid (1153), a plurality of nozzles (1n, 2n, 3n, 4n) receiving injection fluid (1153) from the heated manifold (50), the nozzles each having a respective gate (1g, 2g, 3g, 4g) communicating with one or more cavities (20), each nozzle having a valve comprised of an actuator (1a, 2a, 3a, 4a) and a corresponding valve pin (1p, 2p, 3p, 4p) controllably driven by the actuator to control velocity or pressure of injection fluid flow (1153) through the gates of the nozzles during an injection cycle having a selected duration, the injection cycle comprising a fill phase wherein between about 90% and about 99% of the mold cavity is filled with injection fluid and a subsequent pack phase wherein between about 1% and about 10% of the mold cavity is filled with injection fluid, a controller for controlling pack or fill pressures of the injection fluid injected during the pack and fill phases at preselected positions within the cavity (20) of the mold (35), the controller

the injection machine molding machine injecting injection fluid (1153) on a first injection cycle through each of the gates (1g, 2g, 3g, 4g) of each of the nozzles (1n, 2n, 3n, 4n),

a recorder that records one or both of the pack and fill pressures at each of the selected positions within the one or more mold cavities, a first one or more parts or objects within a corresponding one or more mold cavities (20) being formed during the first injection cycle and inspected or measured by a user of the apparatus to determine and establish an updated pack or fill pressure for each of the selected positions within the one or more mold cavities based on the inspecting or measuring,

the injection molding machine injecting injection fluid (1153) on a successive injection cycle through each of the gates,

the controller including instructions that control the actuators (1a, 2a, 3a, 4a) corresponding to each gate (1g, 2g, 3g, 4g) to adjust positioning of the valve pins (1p, 2p, 3p, 4p) such that pressure or velocity of flow of injection fluid through the gates is adjusted to match the pack or fill pressure for each of the selected positions within the one or more mold cavities (20) to the updated pack or fill pressures.

[0010] In such an apparatus the actuators, valve pins and gates are typically adapted such that the valve pins are controllably drivable between a gate closed position at which injection fluid flow is stopped and pressure is zero at the gate, a fully upstream gate open position at which injection fluid flow is at a maximum velocity and pressure and one or more intermediate upstream positions between the gate closed and fully upstream gate open position at which injection fluid flow pressure and velocity is at a reduced between zero and the maximum,

the controller including instructions that control the actuators to adjust the pressure or velocity of injection fluid flow through the gates during one or more of the successive injection cycles by controlling positioning of a distal end of one or more valve pins relative to an interior surface of a corresponding gate to controllably reduce velocity of flow of the injection fluid to one or more reduced velocities between zero and the maximum velocity.

[0011] The controller preferably includes instructions that control the actuators to withdraw and maintain one or more of the valve pins in at least one selected intermediate upstream position for a selected portion or all of the duration of the injection cycle.

[0012] Most preferably, the controller includes instructions that control the actuators to withdraw and maintain one or more of the valve pins in at least one selected intermediate upstream position for a selected portion or all of the fill and pack phases of the injection cycle.

[0013] In another aspect of the invention there is provided a method for adjusting the simultaneous rate of flow of injection fluid (1153) through each individual gate (1g, 2g, 3g, 4g) of a plurality of nozzles (1n, 2n, 3n, 4n) in an injection molding system (10) wherein the plurality of nozzles are adapted to inject the injection fluid into one or more cavities (20) of one or more molds (35),

wherein an actuator (1a, 2a, 3a, 4a) is interconnected to a valve pin (1p, 2p, 3p, 4p) and mounted and adapted at each gate (1g, 2g, 3g, 4g) of each nozzle to be controllably drivable between a closed gate position where pressure of flow of the injection fluid into a corresponding cavity is zero, a fully gate open position where the injection fluid flows through the gate at a maximum pressure or velocity, and one or more intermediate positions where pressure or velocity of flow of the injection fluid flowing through the gate varies between zero and maximum,

the pressure or velocity of flow of injection fluid through each individual gate of each nozzle being adjusted between two or more successive injection cycles for by:

running a first injection cycle of injection fluid,

recording, during one or both of the fill and pack stages of the first injection cycle, the pressure or velocity of flow of injection fluid at a preselected position within each corresponding cavity,

running a successive injection cycle and adjusting the pressure or velocity of the injection fluid at each preselected position within each cavity during one or both of the fill and pack stages of the successive injection cycle by adjusting the position of each valve pin corresponding to each gate to one or more intermediate positions that increases or decreases the fill or pack pressure at each preselected position to a selected degree relative to the fill or pack pressure that was recorded during the first injection cycle at each preselected position within each cavity.

[0014] In such a method of claim 9 the actuators, valve pins and gates are typically adapted such that the valve pins are controllably drivable between a gate closed position at which injection fluid flow is stopped and pressure is zero at the gate, a fully upstream gate open position at which injection fluid flow is at a maximum velocity and pressure and one or more intermediate upstream positions between the gate closed and fully upstream gate open position at which injection fluid flow pressure and velocity is at a reduced between zero and the maximum,

the pressure or velocity of injection fluid flow through the gates being adjusted during one or more of the successive injection cycles by controlling positioning of a distal end of one or more valve pins relative to an interior surface of a corresponding gate to controllably reduce velocity of flow of the injection fluid to one or more reduced velocities between zero and the maximum velocity.

[0015] In such a method one or more of the valve pins is typically withdrawn and maintained in at least one selected intermediate upstream position for a selected portion or all of the duration of the injection cycle.

[0016] In such a method one or more of the valve pins is typically withdrawn and maintained in at least one selected intermediate upstream position for a selected portion or all of the fill and pack phases of the injection cycle.

[0017] The selected degree to which the fill or pack pressure is adjusted during the successive injection cycle is preferably determined either:

by inspecting a part produced within each cavity during the first injection cycle and increasing or decreasing the fill or pack pressure at each preselected position within each cavity during the successive injection cycle based on the inspection or,

by generating a set of target fill or pack pressures for each cavity calculated from an algorithm using a selected fill time as a variable and increasing or decreasing the fill or pack pressure during the successive injection cycle based on a comparison of the target fill or pack pressures with the fill or pack pressures recorded during the first injection cycle.

[0018] In another aspect of the invention there is provided an injection molding apparatus comprising an injection molding machine, a manifold into which the injection molding machine injects an injection fluid, a plurality of nozzles receiving injection fluid from the heated manifold, each nozzle having a gate through which injection fluid flows into one or more cavities of one or more molds, wherein the apparatus further comprises:

an actuator interconnected to a valve pin and mounted to and adapted at each gate of each nozzle to be controllably drivable between a closed gate position where pressure of flow of the injection fluid into a corresponding cavity is zero, a fully gate open position where the injection fluid flows through the gate at a maximum pressure or velocity, and one or more intermediate positions where pressure or velocity of flow of the injection fluid flowing through the gate varies between zero and maximum, wherein the actuators and corresponding interconnected valve pins and gates are adapted such that the pressure or velocity of flow of injection fluid through each individual gate of each nozzle is controllably adjustable between two or more successive injection cycles for by:

running a first injection cycle of injection fluid,

recording, during one or both of the fill and pack stages of the first injection cycle, the pressure or velocity of flow of injection fluid at a preselected position within each corresponding cavity, and,

running a successive injection cycle and adjusting the pressure or velocity of the injection fluid at each preselected position within each cavity during one or both of the fill and pack stages of the successive injection cycle by adjusting the position of each valve pin corresponding to each gate to one or more intermediate positions that increases or decreases the fill or pack pressure at each preselected position to a selected degree relative to the fill or pack pressure that was recorded during the first injection cycle at each preselected position within each cavity.

[0019] In such an apparatus the apparatus is preferably adapted to enable the selected degree to which the fill or pack pressure is adjusted during the successive injection cycle to be determined either:

by inspecting a part produced within each cavity during the first injection cycle and increasing or decreasing the fill or pack pressure at each preselected position within each cavity during the successive injection cycle based on the inspection or,

by generating a set of target fill or pack pressures for each cavity calculated from an algorithm using a selected fill time as a variable and increasing or decreasing the fill or pack pressure during the successive injection cycle based on a comparison of the target fill or pack pressures with the fill or pack pressures recorded during the first injection cycle.

[0020] In another aspect of the invention there is provided in an injection molding system comprised of an injection molding machine, a heated manifold into which the injection molding machine injects a selected injection fluid, a plurality of nozzles receiving injection fluid from the heated manifold, the nozzles each having a respective gate communicating with the one or more cavities, each nozzle having a valve comprised of an actuator and a corresponding valve pin controllably driven by the actuator to control velocity or pressure of injection fluid flow through the gates of the nozzles, a method for establishing pack or fill pressures of the injection fluid at preselected positions within the mold, the method comprising:

injecting injection fluid on a first injection cycle through each of the gates of each of the nozzles and recording one or both of the pack and fill pressures at each of the selected positions within the one or more mold cavities,

forming a first one or more parts or objects within a corresponding one or more mold cavities during the first injection cycle,

inspecting or measuring the first one or more parts or objects,

determining an updated pack or fill pressure for each of the selected positions within the one or more mold cavities based on the inspecting or measuring,

injecting injection fluid on a successive injection cycle through each of the gates and controlling the actuators corresponding to each gate to adjust positioning of the valve pins such that pressure or velocity of flow of injection fluid through the gates is adjusted to match the pack or fill pressure for each of the selected positions within the one or more mold cavities to the updated pack or fill pressures.

[0021] The valve pins and gates are adapted such that the pressure or velocity of flow of injection fluid through the gates is controllably variable according to the position of the distal end of the valve pin relative to an interior surface of a corresponding gate. The pressure or velocity of flow of injection fluid through the gates is adjusted during a successive injection cycle by controlling positioning of the distal end of the valve pin relative to an interior surface of a corresponding gate to controllably reduce velocity of flow of the injection fluid relative to a maximum velocity. The position of the distal end of the valve pins relative to the interior surface of the corresponding gates is controllable by a program contained in a controller interconnected to and that directs drive of the actuators that drive the valve pins.

[0022] The actuators, valve pins and gates are adapted such that the valve pins are controllably drivable between a gate closed position at which injection fluid flow is stopped and pressure is zero at the gate, a fully upstream gate open position at which injection fluid flow is at a maximum velocity and pressure and one or more intermediate upstream positions between the gate closed and fully upstream gate open position at which injection fluid pressure and velocity is between zero and the maximum. At the beginning of an injection cycle, the valve pins are disposed in the gate closed position and are withdrawn upstream at a velocity that is less than a maximum upstream withdrawal velocity. During an injection cycle, one or more of the valve pins can be withdrawn and maintained in one or more of the intermediate upstream position such that the pressure or velocity of flow of injection fluid is less than the maximum for a selected portion or all of the duration of the injection cycle.

[0023] In accordance with the invention there is provided a method for adjusting the simultaneous rate of flow of injection fluid through each individual gate of a plurality of nozzles in an injection molding system wherein the plurality of nozzles are adapted to inject the injection fluid into one or more cavities of one or more molds,

wherein an actuator is interconnected to a valve pin and mounted and adapted at each gate of each nozzle to be controllably drivable between a closed gate position where pressure of flow of the injection fluid into a corresponding cavity is zero, a fully gate open position where the injection fluid flows through the gate at a maximum pressure or velocity, and one or more intermediate positions where pressure or velocity of flow of the injection fluid flowing through the gate varies between zero and maximum,

the pressure or velocity of flow of injection fluid through each individual gate of each nozzle being adjusted between two or more successive injection cycles for by:

running a first injection cycle of injection fluid,

recording, during one or both of the fill and pack stages of the first injection cycle, the pressure or velocity of flow of injection fluid at a preselected position within each corresponding cavity,

running a successive injection cycle and adjusting the pressure or velocity of the injection fluid at each preselected position within each cavity during one or both of the fill and pack stages of the successive injection cycle by adjusting the position of each valve pin corresponding to each gate to one or more intermediate positions that increases or decreases the fill or pack pressure at each preselected position to a selected degree relative to the fill or pack pressure that was recorded during the first injection cycle at each preselected position within each cavity.

[0024] The selected degree to which the fill or pack pressure is adjusted during the successive injection cycle is typically determined either:

by inspecting a part produced within each cavity during the first injection cycle and increasing or decreasing the fill or pack pressure at each preselected position within each cavity during the successive injection cycle based on the inspection or,

by generating a set of target fill or pack pressures for each cavity calculated from an algorithm using a selected fill time as a variable and increasing or decreasing the fill or pack pressure during the successive injection cycle based on a comparison of the target fill or pack pressures with the fill or pack pressures recorded during the first injection cycle.

[0025] The step of running a successive injection cycle and adjusting the pressure or velocity of the injection fluid is typically repeated one or more times by recording the fill or pack pressures or velocities in the successive injection cycle and increasing or decreasing the fill or pack pressures a selected degree in the next successive injection cycle relative to the recorded fill or pack pressure recorded.

[0026] Each gate and each corresponding actuator and valve pin are adapted such that the valve pin is controllably positionable at one or more of the intermediate positions during the course of an injection cycle.

[0027] Each gate and each corresponding valve pin are adapted to enable the pressure or velocity of flow of injection fluid through a corresponding gate to progressively increase from zero to the maximum pressure or velocity as a valve pin travels from the gate closed position to a selected upstream fully open position. Conversely each gate and each corresponding valve pin are adapted to enable the pressure or velocity of flow of injection fluid through a corresponding gate to progressively decrease from the maximum pressure or velocity to zero as a valve pin travels from the selected upstream fully open position to the gate closed position.

[0028] In another aspect of the invention there is provided an injection molding apparatus comprising an injection molding machine, a manifold into which the injection molding machine injects an injection fluid, a plurality of nozzles receiving injection fluid from the heated manifold, each nozzle having a gate through which injection fluid flows into one or more cavities of one or more molds, wherein the apparatus further comprises:

an actuator interconnected to a valve pin and mounted to and adapted at each gate of each nozzle to be controllably drivable between a closed gate position where pressure of flow of the injection fluid into a corresponding cavity is zero, a fully gate open position where the injection fluid flows through the gate at a maximum pressure or velocity, and one or more intermediate positions where pressure or velocity of flow of the injection fluid flowing through the gate varies between zero and maximum,

wherein the actuators and corresponding interconnected valve pins and gates are adapted such that the pressure or velocity of flow of injection fluid through each individual gate of each nozzle is controllably adjustable between two or more successive injection cycles for by:

running a first injection cycle of injection fluid,

recording, during one or both of the fill and pack stages of the first injection cycle, the pressure or velocity of flow of injection fluid at a preselected position within each corresponding cavity, and,

running a successive injection cycle and adjusting the pressure or velocity of the injection fluid at each preselected position within each cavity during one or both of the fill and pack stages of the successive injection cycle by adjusting the position of each valve pin corresponding to each gate to one or more intermediate positions that increases or decreases the fill or pack pressure at each preselected position to a selected degree relative to the fill or pack pressure that was recorded during the first injection cycle at each preselected position within each cavity.

[0029] The apparatus is preferably adapted to enable the selected degree to which the fill or pack pressure is adjusted during the successive injection cycle to be determined either:

by inspecting a part produced within each cavity during the first injection cycle and increasing or decreasing the fill or pack pressure at each preselected position within each cavity during the successive injection cycle based on the inspection or,

by generating a set of target fill or pack pressures for each cavity calculated from an algorithm using a selected fill time as a variable and increasing or decreasing the fill or pack pressure during the successive injection cycle based on a comparison of the target fill or pack pressures with the fill or pack pressures recorded during the first injection cycle.

[0030] The apparatus is preferably adapting to enable the running of a successive injection cycle and adjusting the pressure or velocity of the injection fluid to be repeated one or more times by recording the fill or pack pressures or velocities in the successive injection cycle and increasing or decreasing the fill or pack pressures a selected degree in the next successive injection cycle relative to the recorded fill or pack pressure recorded.

[0031] Each gate and each corresponding actuator and valve pin are adapted such that the valve pin is controllably positionable at one or more of the intermediate positions during the course of an injection cycle.

[0032] Each gate and each corresponding valve pin are adapted to enable the pressure or velocity of flow of injection fluid through a corresponding gate to progressively increase from zero to the maximum pressure or velocity as a valve pin travels from the gate closed position to a selected upstream fully open position. Conversely each gate and each corresponding valve pin are adapted to enable the pressure or velocity of flow of injection fluid through a corresponding gate to progressively decrease from the maximum pressure or velocity to zero as a valve pin travels from the selected upstream fully open position to the gate closed position.

Brief Description of the Drawings

[0020] The above and further advantages of the invention may be better understood by referring to the following description in conjunction with the accompanying drawings in which:

[0021] Fig. 1 is a schematic of an embodiment of the invention showing a single mold cavity having multiple valves with multiple gates injecting injection fluid into the cavity of a mold at a variety of spaced apart positions along the length, width and contour of the mold and mold cavity, and illustrating an example of fill and pack pressure data recorded during the course of a first and a second subsequent injection cycle by cavity sensors disposed at selected positions within the cavity relative to each gate of each valve.

[035] Fig. 2 is a schematic of one embodiment of the invention showing generically a hydraulically actuated valve pin in which at least one port of the actuator is connected to a flow restrictor so as to restrict the flow of hydraulic drive fluid and slow the opening of the valve pin by a selected lessening of pin opening velocity by use of a controller interconnected to the flow restrictor, the controller enabling the user to select a percentage of predetermined full open position velocity that the hydraulic drive supply to the actuator normally operates at full open velocity drive fluid pressure.

[036] Figs. 2A, 2B are schematic cross-sectional views of the hydraulic valves and restrictors used in the system of Fig. 1 according to the invention.

[037] Figs. 3A-3B show tapered end valve pin positions at various times and positions between a starting closed position as in Fig. 3A and various upstream opened positions, RP representing a selectable path length over which the velocity of withdrawal of the pin upstream from the gate closed position to an open position is reduced (via a controllable flow restrictor) relative to the velocity of upstream movement that the valve pin would normally have over the uncontrolled velocity path FOV when the hydraulic pressure is normally at full pressure and pin velocity is at its maximum.

[038] Figs. 4A-4B show a system having a valve pin that has a cylindrically configured tip end, the tips ends of the pins being positioned at various times and positions between a starting closed position as in Fig. 4A and various upstream opened positions, RP wherein RP represents a path of selectable length over which the velocity of withdrawal of the pin upstream from the gate closed position to an open position is reduced (via a controllable flow restrictor or electric actuator) relative to the velocity of upstream movement that the valve pin would normally have over the uncontrolled velocity path FOV when the hydraulic pressure of a hydraulic actuator is normally at full pressure and pin velocity is at its maximum.

[0039] Figs. 5A-5D are a series of plots of pin velocity versus position each plot representing a different example of the opening of a gate lateral to a central gate via continuous upstream withdrawal of a valve pin at one rate or set of rates over an initial flow path RP and at another higher rate or set of rates of upstream withdrawal of the valve pin beginning at a pin position of FOP and beyond when the fluid material flow is typically at a maximum unrestricted rate of flow through the open gate without any restriction or obstruction from the tip end of the pin.

DETAILED DESCRIPTION

[0040] Fig. 1 shows an injection molding system 10 according to the invention comprised of an injection molding machine 40 that injects a preselected injection molding fluid into a heated fluid distribution manifold 50 that distributes heated injection fluid to a plurality of valves 1, 2, 3, 4 each comprised of a respective nozzle 1n, 2n, 3n, 4n and valve pin 1p, 2p, 3p, 4p that are interconnected to respective actuators 1a, 2a, 3a, 4a that can controllably drive the pins 1p, 2p, 3p, 4p reciprocally back and forth UD along the axes of the pins between gate closed and fully gate open positions.

[0041] As shown in Fig. 1, the cavity pressure sensors 1s, 2s, 3s, 4s are purposely positioned within the volume of the cavity 20, 20d at selected positions near enough, typically within about 0.1 to about 2 inches, a respective gate 1g, 2g, 3g, 4g that enables the sensors 1s, 2s, 3s, 4s to record a fluid pressure within the cavity that is indicative of the pressure or rate or flow or velocity of injection fluid that exits through a respective gate 1g, 2g, 3g, 4g into the cavity at about the position of the gate into the cavity 20, 20d.

[0042] As shown for example, a first injection cycle, Cycle 1, is carried out employing an injection pressure from the injection machine 40 into the heated manifold 50 that is at least sufficient to ensure that the entire volume of the cavity 20, 20d is filled with injection fluid within a selected period of preselected fill time, for example within 5 seconds or 8 seconds or 10 seconds, the amount of fill time being selected by the user of the apparatus based on the size and configuration of the mold cavity.

[0043] The pressure of injection fluid that is generated by the injection molding machine 40 (which is typically determined by the machine's 40 screw speed, screw size, screw configuration, barrel size, barrel and screw temperatures and barrel configuration) can be selected for use in Cycle 1 (or in any other cycle) by first calculating a most preferred injection molding machine 40 injection pressure by use of an algorithm that utilizes the three-dimensional volume and configuration of the mold cavity 20 and the user preselected preferred fill time of the mold cavity 20 as variables to calculate other system parameters such as injection machine pressure, nozzle channel pressure, cavity pressures in specific locations or positions within the volume of the known cavity configuration. Such an algorithm typically also utilizes as variables in calculating injection and cavity pressures, the mold 35 temperature and the melt temperature of the selected injection fluid material (for example the melt temperature of thermoplastic olefins (TPOs), polycarbonates, polyesters, polypropylene, polyurethanes, polyamides, or blends of these with, for instance, glass fibers, for strength and structural rigidity, or PET, polyethylene or the like).

[0044] During the course of the initial Cycle 1, the pressure of the injection fluid at the selected internal cavity positions of each cavity sensor 1s, 2s, 3s, 4s during the fill and pack portions of the duration of Cycle 1 are recorded. By way of example, if Cycle 1 were selected to be 8 seconds long, the fill portion might be the first 4-7 seconds and the pack portion might be the last 1-4 seconds.

[0045] After such a Cycle 1 is carried out and the fill and pack pressures are recorded, the part or object that is formed and molded within the cavity 20, 20d is visually and manually inspected and measured to determine the completeness, uniformity and degree of injection fluid hardness, density, visual appearance, strength, opacity and the like. Depending on the results the inspection, the user determines roughly whether and to what degree the fill or pack pressures need to be adjusted in order to achieve a higher quality or better result in terms of completeness, uniformity and degree of injection fluid hardness, density, visual appearance, strength, opacity and the like. Once a degree of preferred adjustment in pack and fill pressures is determined by the user, a controller 16 as discussed for example below is programmed to control operation of the valve pins 1p, 2p, 3p, 4p during the course of a second subsequent Cycle 2 to produce an injection Cycle 2 that has the adjusted pack and fill pressures as shown in Figure 1 as measured by cavity sensors 1s, 2s, 3s, 4s.

[0046] At the conclusion of Cycle 2 the user once again can visually and manually inspect and measure the part or object that is formed and molded within the cavity 20, 20d to determine the completeness, uniformity and degree of injection fluid hardness, density, visual appearance, strength, opacity and the like. Again, depending on the results the inspection, the user determines roughly whether and to what degree the fill or pack pressures need to be adjusted. Again once a degree of preferred adjustment in pack and fill pressures is determined by the user, a controller 16 as discussed for example below can be programmed to control operation of the valve pins 1p, 2p, 3p, 4p during the course of another subsequent cycle, Cycle 3 that has newly adjusted pack and fill pressures. As can be readily imagined the above described process can be carried out for as many successive cycles of injection and inspection and adjustment as the user believes is necessary to achieve an acceptable molded part or object.

[0047] As shown by way of example in Fig. 1, in a typical single cavity large part mold 35, pressure of the injection fluid in the distal portion 20d of is generally lower than the pressure in the proximal 20p portion of the cavity 20 due to the location of the nozzles. Therefore as shown in Fig. 1, on carrying out Cycle 2 in order to more uniformly pack the volume of the cavity relative to the uniformity that was determined from the part or object produced in Cycle 1, the pack pressure in Cycle 2 is increased at the distal locations of sensors 1s and 4s by increasing the rate of flow of injection fluid through gates 1g and 4g relative to gates 2g and 3g during the pack pressure portion of the duration of Cycle 2.

[0048] The valve pins 1p, 2p, 3p, 4p and their associated actuators 1a, 2a, 3a, 4a and gates 1g, 2g, 3g, 4g are adapted and configured such that the velocity of flow of injection fluid through the gates can be variably controlled such that the pressure or velocity of flow of injection fluid through a corresponding gate progressively increases from zero to a selected maximum pressure or velocity (as occurs when a valve pin is in a fully gate open position) as a valve pin travels from the gate closed position to a selected upstream fully open position. Conversely each gate 1g, 2g, 3g, 4g and each corresponding valve pin 1p, 2p, 3p, 4p are adapted to enable the pressure or velocity of flow of injection fluid through a corresponding gate to progressively decrease from the maximum pressure or velocity to zero as a valve pin travels from the selected upstream fully open position to the gate closed position.

[0049] An example of an actuator system for driving any one or more of valve pins 1p, 2p, 3p, 4p is shown in Figs 2A, 2B. Valve pin 1041 corresponds to pins 1p, 2p, 3p, 4p and actuators 951, 952 correspond to actuators 1a, 2a, 3a, 4a of Fig. 1. As shown in Figs. 2A, 2B, a supply of hydraulic fluid 14 is fed first through a directional control valve 750 mechanism that switches the hydraulic fluid flow to the actuator cylinders in either of two directions: fluid out to withdraw the pin upstream, Fig. 2A, and fluid in to drive the pin downstream, Fig. 2B. At the beginning of an injection cycle the gate of a lateral valve 34, 36 is closed and the hydraulic system is in the directional configuration of Fig. 2B. When a cycle is started, the directional configuration of the directional valve 750 of the hydraulic system 700 is switched by controller 16 to the configuration of Fig. 2A. The hydraulic system includes a flow restriction valve 600 that can vary the rate of flow of hydraulic fluid to the actuator 951 under the control of the controller 16 to vary the rate of travel, upstream or downstream of the piston of the actuator 951 which in turn controls the direction and rate of travel of valve pin 1041. Although not shown in Figs. 2A, 2B, the hydraulic system 700 controls the direction and rate of travel of the pistons of actuators 950 and 952 in a manner similar to the manner of control of actuator 951 via the connections shown in Fig. 1.

[0050] In one example, the user programs controller 16 via data inputs on a user interface to instruct the hydraulic system 700 to drive pins 1041, 1042 at an upstream velocity of travel that is reduced relative to a maximum velocity that the hydraulic system can drive the pins 1041, 1042 to travel. As described below, such reduced pin withdrawal rate or velocity is executed until a position sensor such as

951, 952 detects that an actuator 941, 952 or an associated valve pin (or another component), has reached a certain position such as the end point COP, COP2, Figs. 3B, 4B of a restricted flow path RP, RP2. A typical amount of time over which the pins are withdrawn at a reduced velocity is between about 0.01 and .10 second, the entire injection cycle time typically being between about 0.3 seconds and about 3 seconds, more typically between about 0.5 seconds and about 1.5 seconds. In larger sized cavity systems, the times of withdrawal at reduced velocity and the entire injection cycle time can be greater such as between about 0.01 and 5 seconds and for reduced velocity withdrawal time and between about 0.5 and 20 seconds for entire cycle time.

[0051] In one embodiment, the user can select one or more of the valves, 1a-4a, 1p-4p, to act as a master valve(s) which is the first in time valve to be opened at the beginning of the injection cycle (where all of the valve pins are initially disposed at the start or beginning of the cycle in a gate closed position), the other valves 2a, 3a, 2p, 3p being disposed downstream of the selected master gate and opened later in time after the selected master valve is first opened.

[0052] The “fill phase” of an injection cycle is that portion of the injection cycle where one or more of the gates 1g-4g are opened and a selected percentage of between about 90% and about 99% of the volume of the cavity 20 is filled with the selected injection fluid.

[0053] Conversely, the “pack phase” of the injection cycle is that portion of an injection cycle where a selected portion of the remaining volume of the cavity of between about 1% and about 10% of the mold cavity that was not filled during the fill phase is still in process of being filled with injection fluid at the end of the injection cycle after the fill phase is complete.

[0054] In such an embodiment the master valve is opened such that

- the master valve gate(s) is either first fully and then partially opened during the fill phase or is only partially opened during the entire fill phase
- the master valve gate(s) is next partially opened during the entire pack phase
- and subsequently closed at the end of the pack phase

[0055] In such an embodiment, the downstream gate(s) that are downstream of the selected master gate(s) is or are opened after the flow front of injection fluid within the mold cavity reaches or travels to a selected position within the cavity 20 relative to the downstream gate(s), typically when the fluid flow front has travelled to a selected position downstream of the downstream gate. The downstream gate(s) is either first fully opened (where maximum velocity fluid flow occurs) and then partially opened (where reduced velocity fluid flow occurs) or is only partially opened during the entire fill phase, and then only partially opened during the entire pack phase.

[0056] Position sensors are typically used for sensing the position of the actuator cylinders and their associated valve pins and feed such position information to controller 16 for monitoring purposes. As shown, fluid material is injected from an injection machine into a manifold runner 19 and further downstream into the bores 44, 46 of the lateral nozzles 24, 22 and ultimately downstream through the gates 32, 34, 36. When the pins 1041, 1042 are withdrawn upstream to a position where the tip end of the pins 1041 are in a fully upstream open position such as shown in Fig. 1D, the rate of flow of fluid material through the gates 34, 36 is at a maximum. However when the pins 1041, 1042 are initially withdrawn beginning from the closed gate position, Fig. 1A, to intermediate upstream positions, Figs. 1B, 1C, a gap 1154, 1156 that restricts the velocity of fluid material flow is formed between the outer surfaces 1155 of the tip end of the pins 44, 46 and the inner surfaces 1254, 1256 of the gate areas of the nozzles 24, 20. The restricted flow gap 1154, 1156 remains small enough to restrict and reduce the rate of flow of fluid material 1153 through gates 34, 36 to a rate that is less than maximum flow velocity over a travel distance RP of the tip end of the pins 1041, 1042 going from closed to upstream as shown in Figs. 1, 1B, 1C, 1E and 3B, 4B.

[0057] The pins 1041 can be controllably withdrawn at one or more reduced velocities (less than maximum) for one or more periods of time over the entirety of the length of the path RP over which flow of mold material 1153 is restricted. Preferably the pins are withdrawn at a reduced velocity over more than about 50% of RP and most preferably over more than about 75% of the length RP. As described below with reference to Figs. 3B, 4B, the pins 1041 can be withdrawn at a higher or maximum velocity at the end COP2 of a less than complete restricted mold material flow path RP2.

[0058] The trace or visible lines that appear in the body of a part that is ultimately formed within the cavity of the mold on cooling above can be reduced or eliminated by reducing or controlling the velocity of the pin 1041, 1042 opening or upstream withdrawal from the gate closed position to a selected intermediate upstream gate open position that is preferably 75% or more of the length of RP.

[0059] RP can be about 1-8 mm in length and more typically about 2-6 mm and even more typically 2-4 mm in length. As shown in Fig. 2 in such an embodiment, a control system or controller 16 is preprogrammed to control the sequence and the rates of valve pin 1040, 1041, 1042 opening and closing. The controller 16 controls the rate of travel, namely velocity of upstream travel, of a valve pin 1041, 1042 from its gate closed position for at least the predetermined amount of time that is selected to withdraw the pin at the selected reduced velocity rate.

[0060] The velocity of withdrawal of the valve pins 1041, 1042 is determined by regulation of the flow of hydraulic drive fluid that is pumped from a supply 14 to the actuators 941, 942 through a flow restrictor valve 600, Figs. 1, 2, 2A, 2B. When the flow restrictor valve 600 is completely open, namely 100% open, allowing maximum flow of the pressurized hydraulic fluid to the actuator cylinders, the valve pins 1041, 1042 are driven at a maximum upstream travel velocity. According to the invention, the degree of openness of the flow restrictor valve is adjusted in response to sensing of position of a suitable component such as an actuator 941, 942 or associated valve pin to less than 100% open. Adjustment of the flow restrictor valve 600 to less than 100% open thus reduces the rate and volume flow of pressurized hydraulic fluid to the actuator cylinders thus in turn reducing the velocity of upstream travel of the pins 1041, 1042 for the selected period of time. At the end of the travel or length of path RP, RP2, a position sensor signals the controller 16, the controller 16 determines that the end COP, COP2 has been reached and the valve 600 is opened to a higher velocity, typically to its 100% open position to allow the actuator pistons and the valve pins 1041, 1042 to be driven at maximum upstream velocity FOV in order to reduce the cycle time of the injection cycle.

[0061] The valve 600 typically comprises a restrictor valve that is controllably positionable anywhere between completely closed (0% open) and completely open (100% open). Adjustment of the position of the restrictor valve 600 is typically accomplished via a source of electrical power that controllably drives an electromechanical mechanism that causes the valve to rotate such as a rotating spool that reacts to a magnetic or electromagnetic field created by the electrical signal output of the controller 16, namely an output of electrical energy, electrical power, voltage, current or amperage the degree or amount of which can be readily and controllably varied by conventional electrical output devices. The electro-mechanism is controllably drivable to cause the valve 600 to open or close to a degree of openness that is proportional to the amount or degree of electrical energy that is input to drive the electro-mechanism. The velocity of upstream withdrawal travel of the pins 1041, 1042 are in turn proportional to the degree of openness of the valve 600. Thus the rate of upstream travel of the pins 1041, 1042 is proportional to the amount or degree of electrical energy that is input to the electro-mechanism drives valves 600. The electro-mechanism that is selected for driving the valve 600 establishes in the first instance the maximum amount of electrical energy or power (such as voltage or current) that is required to open the valve to its 100% open position. A control for setting the amount or degree of electrical energy or power input to the motor is contained within the controller 16. Controller 16 includes an interface that enables the user to input any selected fraction or percentage of the maximum electrical energy or power needed to adjust the valve 600 to less than 100% open for beginning from the gate closed position of the valve pins 1041, 1042 and their associated actuators 941, 942. Thus the user selects a reduced upstream velocity of the pins 1041, 1042 by inputting to the controller 16 a percentage of the maximum amount of electrical energy or power input (voltage or current) needed to open the valve 600 to 100% open. The user inputs such selections into the controller 16. The user also selects the length of the path of travel RP, RP2 of the valve pin or the position of the valve pin or other component over the course of travel of which the valve 600 is to be maintained partially open and inputs such selections into the controller 16. The controller 16 includes conventional programming or circuitry that receives and executes the user inputs. The controller may include programming or circuitry that enables the user to input as a variable a selected pin velocity rather than a percentage of electrical output, the programming of the controller 16 automatically converting the inputs by the user to appropriate instructions for reduced energy input to the electro-mechanism that drives the valve 600.

[0062] Typically the user selects one or more reduced velocities that are less than about 90% of the maximum velocity (namely velocity when the valve 600 is fully open), more typically less than about 75% of the maximum velocity and even more typically less than about 50% of the maximum velocity at which the pins 1041, 1042 are drivable by the hydraulic system. The actual maximum velocity at which the actuators 941, 942 and their associated pins 1041, 1042 are driven is predetermined by selection of the size and configuration of the actuators 941, 942, the size and configuration of the restriction valve 600 and the degree of pressurization and type of hydraulic drive fluid selected for use by the user. The maximum drive rate of the hydraulic system is predetermined by the manufacturer and the user of the system and is typically selected according to the application, size and nature of the mold and the injection molded part to be fabricated.

[0063] As shown by the series of examples of programs illustrated in Figs. 5A-5D one or more reduced pin velocities can be selected and the pin driven by restricted hydraulic fluid flow (or by reduced velocity drive by an electric actuator) between the gate closed (X and Y axis zero position) and the final intermediate upstream open gate position (4mm for example in the Fig. 5A example, 5mm in the Fig. 5B example) at which point the controller 16 in response to position sensing instructs the drive system to drive pin 1041, 1042 to travel upstream at a higher, typically maximum, upstream travel velocity (as shown, 100 mm/sec in the Figs. 5A-5D examples). In the Fig. 5A example, the reduced pin velocity is selected as 50 mm/sec. In practice the actual velocity of the pin may or may not be precisely known, the Y velocity axis corresponding (and generally being proportional) to the degree of electrical energy input to the motor that controls the opening of the flow restriction valve, 100 mm/sec corresponding to the valve 600 being completely 100% open (and pin being driven at maximum velocity); and 50 mm/sec corresponding to 50% electrical energy input to the electromechanism that drives the restriction valve 600 to one-half of its maximum 100% degree of openness. In the Fig. 5A example, the path length RP over which the valve pin 1041, 1042 travels at the reduced 50 mm/sec velocity is 4mm. After the pin 1041, 1042 has been driven to the upstream position COP position of about 4mm from the gate closed GC position, the controller 16 instructs the electro-mechanism that drives the valve 600 (typically a magnetic or electromagnetic field driven device such as a spool) to open the restrictor valve 600 to full 100% open at which time the pin (and its associated actuator piston) are driven by the hydraulic system at the maximum travel rate 100 mm/sec for the predetermined, given pressurized hydraulic system.

[0064] Figs. 5B – 5D illustrate a variety of alternative examples for driving the pin 1041, 1042 at reduced velocities for various durations of time. For example as shown in Fig. 5B, the pin is driven for .02 seconds at 25 mm/sec, then for .06 seconds at 75 mm/sec and then allowed to go to full valve open velocity shown as 100 mm/sec. Full valve open or maximum velocity is typically determined by the nature of hydraulic (or pneumatic) valve or motor drive system that drives the valve pin. In the case of a hydraulic (or pneumatic) system the maximum velocity that the system is capable of implementing is determined by the nature, design and size of the pumps, the fluid delivery channels, the actuator, the drive fluid (liquid or gas), the restrictor valves and the like.

[0065] As shown in Figs. 5A-5D, the velocity of the valve pin when the pin reaches the end of the reduced velocity period, the valve 600 can be instructed to assume the full open position essentially instantaneously or alternatively can be instructed to take a more gradual approach up, between .08 and .12 seconds, to the maximum valve openness as shown in Fig. 5D. In all cases the controller 16 instructs the valve pin 1041, 1042 to travel continuously upstream rather than follow a profile where the pin might travel in a downstream direction during the course of the injection cycle. Most preferably, the actuator, valve pin, valves and fluid drive system are adapted to move the valve pin between a gate closed position and a maximum upstream travel position that defines an end of stroke position for the actuator and the valve pin. Most preferably the valve pin is moved at the maximum velocity at one or more times or positions over the course of upstream travel of the valve pin past the upstream gate open position. Alternatively to the hydraulic system depicted and described, a pneumatic or gas driven system can be used and implemented in the same manner as described above for a hydraulic system.

[0066] Preferably, the valve pin and the gate are configured or adapted to cooperate with each other to restrict and vary the rate of flow of fluid material 1153, Figs. 3A-3B, 4A-4B over the course of travel of the tip end of the valve pin through the restricted velocity path RP. Most typically as shown in Figs. 3A, 3B the radial tip end surface 1155 of the end 1142 of pin 1041, 1042 is conical or tapered and the surface of the gate 1254 with which pin surface 1155 is intended to mate to close the gate 34 is complementary in conical or taper configuration. Alternatively as shown in Figs. 4A, 4B, the radial surface 1155 of the tip end 1142 of the pin 1041, 1042 can be cylindrical in configuration and the gate can have a complementary cylindrical surface 1254 with which the tip end surface 1155 mates to close the gate 34 when the pin 1041 is in the downstream gate closed position. In any embodiment, the outside radial surface 1155 of the tip end 1142 of the pin 1041 creates restricted a restricted flow channel 1154 over the length of travel of the tip end 1142 through and along restricted flow path RP that restricts or reduces the volume or rate of flow of fluid material 1153 relative to the rate of flow when the pin 1041, 1042 is at a full gate open position, namely when the tip end 1142 of the pin 1041 has travelled to or beyond the length of the restricted flow path RP (which is, for example the 4 mm upstream travel position of Figs 5A-5C).

[0067] In one embodiment, as the tip end 1142 of the pin 1041 continues to travel upstream from the gate closed GC position (as shown for example in Figs. 3A, 4A) through the length of the RP path (namely the path travelled for the predetermined amount of time), the rate of material fluid flow 1153 through restriction gap 1154 through the gate 34 into the cavity 30 continues to increase from 0 at gate closed GC position to a maximum flow rate when the tip end 1142 of the pin reaches a position FOP (full open position), Figs. 5A-5D, where the pin is no longer restricting flow of injection mold material through the gate. In such an embodiment, at the expiration of the predetermined amount of time when the pin tip 1142 reaches the FOP (full open) position Figs. 5A, 5B, the pin 1041 is immediately driven by the hydraulic system at maximum velocity FOV (full open velocity) typically such that the restriction valve 600 is opened to full 100% open.

[0068] In alternative embodiments, when the predetermined time for driving the pin at reduced velocity has expired and the tip 1142 has reached the end of restricted flow path RP2, the tip 1142 may not necessarily be in a position where the fluid flow 1153 is not still being restricted. In such alternative embodiments, the fluid flow 1153 can still be restricted to less than maximum flow when the pin has reached the changeover position COP2 where the pin 1041 is driven at a higher, typically maximum, upstream velocity FOV. In the alternative examples shown in the Figs. 3B, 4B examples, when the pin has travelled the predetermined path length at reduced velocity and the tip end 1142 has reached the changeover point COP, the tip end 1142 of the pin 1041 (and its radial surface 1155) no longer restricts the rate of flow of fluid material 1153 through the gap 1154 because the gap 1154 has increased to a size that no longer restricts fluid flow 1153 below the maximum flow rate of material 1153. Thus in one of the examples shown in Fig. 3B the maximum fluid flow rate for injection material 1153 is reached at the upstream position COP of the tip end 1142. In another example shown in Fig. 3B 4B, the pin 1041 can be driven at a reduced velocity over a shorter path RP2 that is less than the entire length of the restricted mold material flow path RP and switched over at the end COP2 of the shorter restricted path RP2 to a higher or maximum velocity FOV. In the Figs. 5A, 5B examples, the upstream FOP position is about 4mm and 5mm respectively upstream from the gate closed position. Other alternative upstream FOP positions are shown in Figs. 5C, 5D.

[0069] In another alternative embodiment, shown in Fig. 4B, the pin 1041 can be driven and instructed to be driven at reduced or less than maximum velocity over a longer path length RP3 having an upstream portion UR where the flow of injection fluid mold material is not restricted but flows at a maximum rate through the gate 34 for the given injection mold system. In this Fig. 4B example the velocity or drive rate of the pin 1041 is not changed over until the tip end of the pin 1041 or actuator 941 has reached the changeover position COP3. As in other embodiments, a position sensor senses either that the valve pin 1041 or an associated component has travelled the path length RP3 or reached the end COP3 of the selected path length and the controller receives and processes such information and instructs the drive system to drive the pin 1041 at a higher, typically maximum velocity upstream. In another alternative embodiment, the pin 1041 can be driven at reduced or less than maximum velocity throughout the entirety of the travel path of the pin during an injection cycle from the gate closed position GC up to the end-of-stroke EOS position, the controller 16 being programmed to instruct the drive system for the actuator to be driven at one or more reduced velocities for the time or path length of an entire closed GC to fully open EOS cycle.

[0070] In the Figs. 5A-5D examples, FOV is 100 mm/sec. Typically, when the time period for driving the pin 1041 at reduced velocity has expired and the pin tip 1142 has reached the position COP, COP2, the restriction valve 600 is opened to full 100% open velocity FOV position such that the pins 1041, 1042 are driven at the maximum velocity or rate of travel that the hydraulic system is capable of driving the actuators 941, 942. Alternatively, the pins 1041, 1042 can be driven at a preselected FOV velocity that is less than the maximum velocity at which the pin is capable of being driven when the restriction valve 600 is fully open but is still greater than the selected reduced velocities that the pin is driven over the course of the RP, RP2 path to the COP, COP2 position.

[0071] At the expiration of the predetermined reduced velocity drive time, the pins 1041, 1042 are typically driven further upstream past the COP, COP2 position to a maximum end-of-stroke EOS position. The upstream COP, COP2 position is downstream of the maximum upstream end-of-stroke EOS open position of the tip end 1142 of the pin. The length of the path RP or RP2 is typically between about 2 and about 8 mm, more typically between about 2 and about 6 mm and most typically between about 2 and about 4 mm. In practice the maximum upstream (end of stroke) open position EOS of the pin 1041, 1042 ranges from about 8 mm to about 18 inches upstream from the closed gate position GC.

[0072] The controller 16 includes a processor, memory, user interface and circuitry and/or instructions that receive and execute the user inputs of percentage of maximum valve open or percentage of maximum voltage or current input to the motor drive for opening and closing the restriction valve, time duration for driving the valve pin at the selected valve openings and reduced velocities.

What is claimed is:

1. In an injection molding system (10) comprised of an injection molding machine (40), a heated manifold (50) into which the injection molding machine injects a selected injection fluid (1153), a plurality of nozzles (1n, 2n, 3n, 4n) receiving injection fluid (1153) from the heated manifold (50), the nozzles each having a respective gate (1g, 2g, 3g, 4g) communicating with one or more cavities (20), each nozzle having a valve comprised of an actuator (1a, 2a, 3a, 4a) and a corresponding valve pin (1p, 2p, 3p, 4p) controllably driven by the actuator to control velocity or pressure of injection fluid flow (1153) through the gates of the nozzles during an injection cycle having a selected duration, the injection cycle comprising a fill phase wherein between about 90% and about 99% of the mold cavity is filled with injection fluid and a subsequent pack phase wherein between about 1% and about 10% of the mold cavity is filled with injection fluid,

a method for establishing pack or fill pressures of the injection fluid injected during the pack and fill phases at preselected positions within the cavity (20) of the mold (35), the method comprising:

injecting injection fluid (1153) on a first injection cycle through each of the gates (1g, 2g, 3g, 4g) of each of the nozzles (1n, 2n, 3n, 4n) and recording one or both of the pack and fill pressures at each of the selected positions within the one or more mold cavities,

forming a first one or more parts or objects within a corresponding one or more mold cavities (20) during the first injection cycle,

inspecting or measuring the first one or more parts or objects,

determining an updated pack or fill pressure for each of the selected positions within the one or more mold cavities based on the inspecting or measuring,

injecting injection fluid (1153) on a successive injection cycle through each of the gates and controlling the actuators (1a, 2a, 3a, 4a) corresponding to each gate (1g, 2g, 3g, 4g) to adjust positioning of the valve pins (1p, 2p, 3p, 4p) such that pressure or velocity of flow of injection fluid through the gates is adjusted to match the pack or fill pressure for each of the selected positions within the one or more mold cavities (20) to the updated pack or fill pressures.

2. The method of claim 1 wherein:

the actuators, valve pins and gates are adapted such that the valve pins are controllably drivable between a gate closed position at which injection fluid flow is stopped and pressure is zero at the gate, a fully upstream gate open position at which injection fluid flow is at a maximum velocity and pressure and one or more intermediate upstream positions between the gate closed and fully upstream gate open position at which injection fluid flow pressure and velocity is at a reduced between zero and the maximum,

the pressure or velocity of injection fluid flow through the gates being adjusted during one or more of the successive injection cycles by controlling positioning of a distal end of one or more valve pins relative to an interior surface of a corresponding gate to controllably reduce velocity of flow of the injection fluid to one or more reduced velocities between zero and the maximum velocity.

3. A method according to any of the foregoing claims wherein one or more of the valve pins is withdrawn and maintained in at least one selected intermediate upstream position for a selected portion or all of the duration of the injection cycle.

4. A method according to any of the forgoing claims wherein one or more of the valve pins is withdrawn and maintained in at least one selected intermediate upstream position for a selected portion or all of the fill and pack phases of the injection cycle.

5. Apparatus for adjusting the rate of injection fluid flow comprising an injection molding system (10) comprised of an injection molding machine (40), a heated manifold (50) into which the injection molding machine injects a selected injection fluid (1153), a plurality of nozzles (1n, 2n, 3n, 4n) receiving injection fluid (1153) from the heated manifold (50), the nozzles each having a respective gate (1g, 2g, 3g, 4g) communicating with one or more cavities (20), each nozzle having a valve comprised of an actuator (1a, 2a, 3a, 4a) and a corresponding valve pin (1p, 2p, 3p, 4p) controllably driven by the actuator to control velocity or pressure of injection fluid flow (1153) through the gates of the nozzles during an injection cycle having a selected duration, the injection cycle comprising a fill phase wherein between about 90% and about 99% of the mold cavity is filled with injection fluid and a subsequent pack

phase wherein between about 1% and about 10% of the mold cavity is filled with injection fluid,

a controller for controlling pack or fill pressures of the injection fluid injected during the pack and fill phases at preselected positions within the cavity (20) of the mold (35), the controller

the injection machine molding machine injecting injection fluid (1153) on a first injection cycle through each of the gates (1g, 2g, 3g, 4g) of each of the nozzles (1n, 2n, 3n, 4n),

a recorder that records one or both of the pack and fill pressures at each of the selected positions within the one or more mold cavities, a first one or more parts or objects within a corresponding one or more mold cavities (20) being formed during the first injection cycle and inspected or measured by a user of the apparatus to determine and establish an updated pack or fill pressure for each of the selected positions within the one or more mold cavities based on the inspecting or measuring,

the injection molding machine injecting injection fluid (1153) on a successive injection cycle through each of the gates,

the controller including instructions that control the actuators (1a, 2a, 3a, 4a) corresponding to each gate (1g, 2g, 3g, 4g) to adjust positioning of the valve pins (1p, 2p, 3p, 4p) such that pressure or velocity of flow of injection fluid through the gates is adjusted to match the pack or fill pressure for each of the selected positions within the one or more mold cavities (20) to the updated pack or fill pressures.

6. An apparatus according claim 5 wherein the actuators, valve pins and gates are adapted such that the valve pins are controllably drivable between a gate closed position at which injection fluid flow is stopped and pressure is zero at the gate, a fully upstream gate open position at which injection fluid flow is at a maximum velocity and pressure and one or more intermediate upstream positions between the gate closed and fully upstream gate open position at which injection fluid flow pressure and velocity is at a reduced between zero and the maximum,

the controller including instructions that control the actuators to adjust the pressure or velocity of injection fluid flow through the gates during one or more of the successive injection cycles by controlling positioning of a distal end of one or more valve pins relative to an interior surface of a corresponding gate to controllably reduce velocity of flow of the injection fluid to one or more reduced velocities between zero and the maximum velocity.

7. The apparatus of any of the foregoing claims 5-6 wherein the controller includes instructions that control the actuators to withdraw and maintain one or more of the valve pins in at least one selected intermediate upstream position for a selected portion or all of the duration of the injection cycle.

8. The apparatus of any of the foregoing claims 5-7 wherein the controller includes instructions that control the actuators to withdraw and maintain one or more of the valve pins in at least one selected intermediate upstream position for a selected portion or all of the fill and pack phases of the injection cycle.

9. A method for adjusting the simultaneous rate of flow of injection fluid (1153) through each individual gate (1g, 2g, 3g, 4g) of a plurality of nozzles (1n, 2n, 3n, 4n) in an injection molding system (10) wherein the plurality of nozzles are adapted to inject the injection fluid into one or more cavities (20) of one or more molds (35),

wherein an actuator (1a, 2a, 3a, 4a) is interconnected to a valve pin (1p, 2p, 3p, 4p) and mounted and adapted at each gate (1g, 2g, 3g, 4g) of each nozzle to be controllably drivable between a closed gate position where pressure of flow of the injection fluid into a corresponding cavity is zero, a fully gate open position where the injection fluid flows through the gate at a maximum pressure or velocity, and one or more intermediate positions where pressure or velocity of flow of the injection fluid flowing through the gate varies between zero and maximum,

the pressure or velocity of flow of injection fluid through each individual gate of each nozzle being adjusted between two or more successive injection cycles for by:

running a first injection cycle of injection fluid,

recording, during one or both of the fill and pack stages of the first injection cycle, the pressure or velocity of flow of injection fluid at a preselected position within each corresponding cavity,

running a successive injection cycle and adjusting the pressure or velocity of the injection fluid at each preselected position within each cavity during one or both of the fill and pack stages of the successive injection cycle by adjusting the position of each valve pin corresponding to each gate to one or more intermediate positions that increases or decreases the fill or pack pressure at each preselected position to a selected degree relative to the fill or pack pressure that was recorded during the first injection cycle at each preselected position within each cavity.

10. The method of claim 9 wherein:

the actuators, valve pins and gates are adapted such that the valve pins are controllably drivable between a gate closed position at which injection fluid flow is stopped and pressure is zero at the gate, a fully upstream gate open position at which injection fluid flow is at a maximum velocity and pressure and one or more intermediate upstream positions between the gate closed and fully upstream gate open position at which injection fluid flow pressure and velocity is at a reduced between zero and the maximum,

the pressure or velocity of injection fluid flow through the gates being adjusted during one or more of the successive injection cycles by controlling positioning of a distal end of one or more valve pins relative to an interior surface of a corresponding gate to controllably reduce velocity of flow of the injection fluid to one or more reduced velocities between zero and the maximum velocity.

11. A method according to any of the foregoing claims 9-10 wherein one or more of the valve pins is withdrawn and maintained in at least one selected intermediate upstream position for a selected portion or all of the duration of the injection cycle.

12. A method according to any of the forgoing claims 9-11 wherein one or more of the valve pins is withdrawn and maintained in at least one selected intermediate upstream position for a selected portion or all of the fill and pack phases of the injection cycle.

13. A method according to any of the foregoing claims 9-12 wherein the selected degree to which the fill or pack pressure is adjusted during the successive injection cycle is determined either:

by inspecting a part produced within each cavity during the first injection cycle and increasing or decreasing the fill or pack pressure at each preselected position within each cavity during the successive injection cycle based on the inspection or,

by generating a set of target fill or pack pressures for each cavity calculated from an algorithm using a selected fill time as a variable and increasing or decreasing the fill or pack pressure during the successive injection cycle based on a comparison of the target fill or pack pressures with the fill or pack pressures recorded during the first injection cycle.

14. An injection molding apparatus comprising an injection molding machine, a manifold into which the injection molding machine injects an injection fluid, a plurality of nozzles receiving injection fluid from the heated manifold, each nozzle having a gate through which injection fluid flows into one or more cavities of one or more molds, wherein the apparatus further comprises:

an actuator interconnected to a valve pin and mounted to and adapted at each gate of each nozzle to be controllably drivable between a closed gate position where pressure of flow of the injection fluid into a corresponding cavity is zero, a fully gate open position where the injection fluid flows through the gate at a maximum pressure or velocity, and one or more intermediate positions where pressure or velocity of flow of the injection fluid flowing through the gate varies between zero and maximum,

wherein the actuators and corresponding interconnected valve pins and gates are adapted such that the pressure or velocity of flow of injection fluid through each individual gate of each nozzle is controllably adjustable between two or more successive injection cycles for by:

running a first injection cycle of injection fluid,

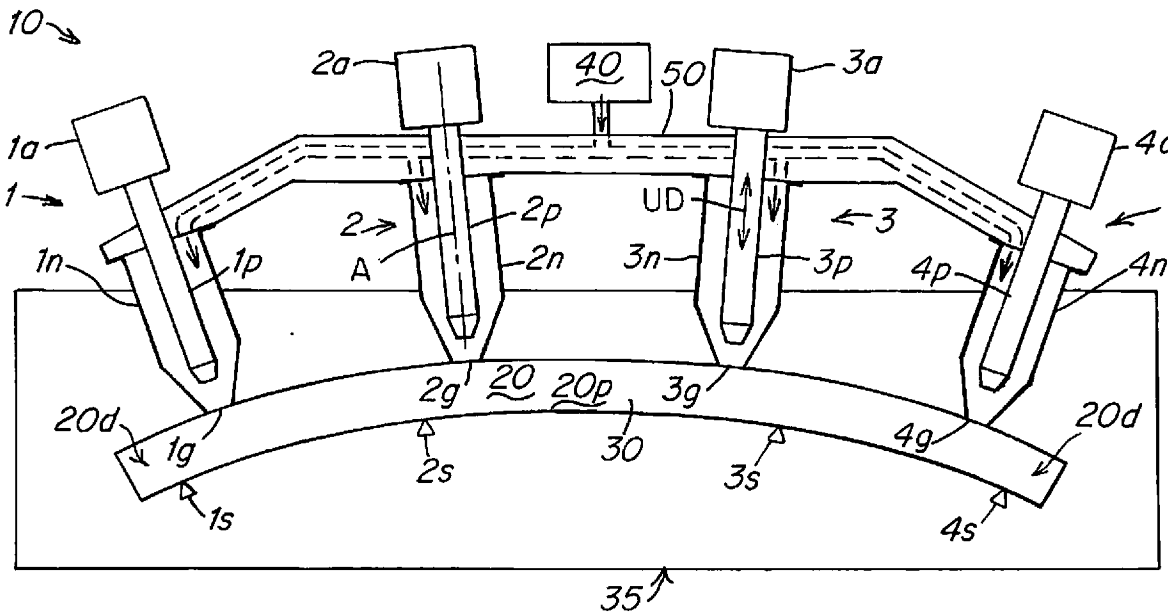
recording, during one or both of the fill and pack stages of the first injection cycle, the pressure or velocity of flow of injection fluid at a preselected position within each corresponding cavity, and,

running a successive injection cycle and adjusting the pressure or velocity of the injection fluid at each preselected position within each cavity during one or both of the fill and pack stages of the successive injection cycle by adjusting the position of each valve pin corresponding to each gate to one or more intermediate positions that increases or decreases the fill or pack pressure at each preselected position to a selected degree relative to the fill or pack pressure that was recorded during the first injection cycle at each preselected position within each cavity.

15. The apparatus of claim 14 wherein the apparatus is adapted to enable the selected degree to which the fill or pack pressure is adjusted during the successive injection cycle to be determined either:

by inspecting a part produced within each cavity during the first injection cycle and increasing or decreasing the fill or pack pressure at each preselected position within each cavity during the successive injection cycle based on the inspection or,

by generating a set of target fill or pack pressures for each cavity calculated from an algorithm using a selected fill time as a variable and increasing or decreasing the fill or pack pressure during the successive injection cycle based on a comparison of the target fill or pack pressures with the fill or pack pressures recorded during the first injection cycle.



	NOZZLE			
	1n	2n	3n	4n
Cycle 1 Fill Pressure	1000	1000	1000	1000
Pack Pressure	700	1000	1000	500
Cycle 2 Fill Pressure	700	850	850	700
Pack Pressure	1600	500	500	1600

Fig. 1

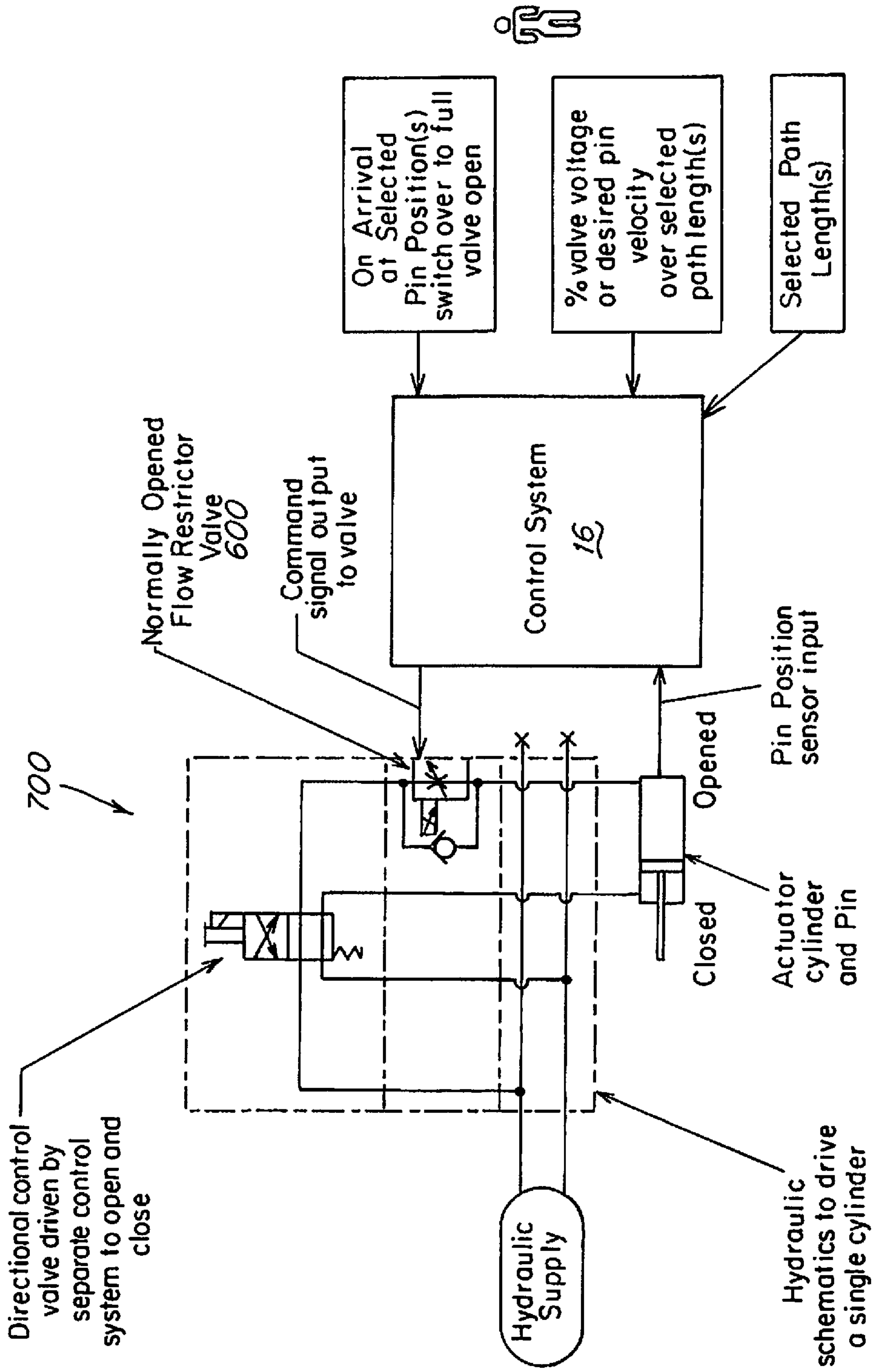

On Arrival at Selected Pin Position(s) switch over to full valve open
% valve voltage or desired pin velocity over selected path length(s)
Selected Path Length(s)
Normally Opened Flow Restrictor Valve 600
Command signal output to valve
Control System 16
700
Pin Position sensor input
Opened
Closed
Actuator cylinder and Pin
Directional control valve driven by separate control system to open and close
Hydraulic Supply
Hydraulic schematics to drive a single cylinder

Fig. 2

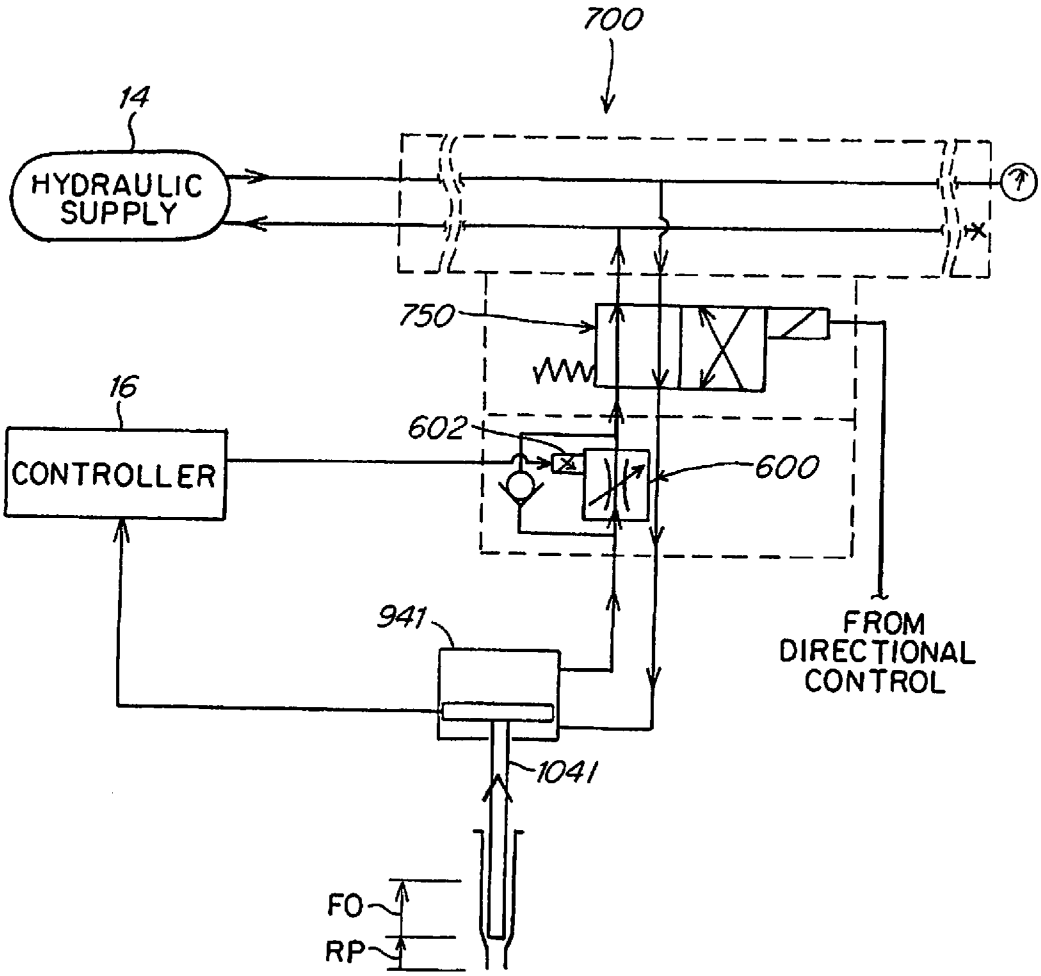

700
14
HYDRAULIC SUPPLY
750
16
CONTROLLER
602
600
941
FROM DIRECTIONAL CONTROL
1041
FO
RP

Fig. 2A

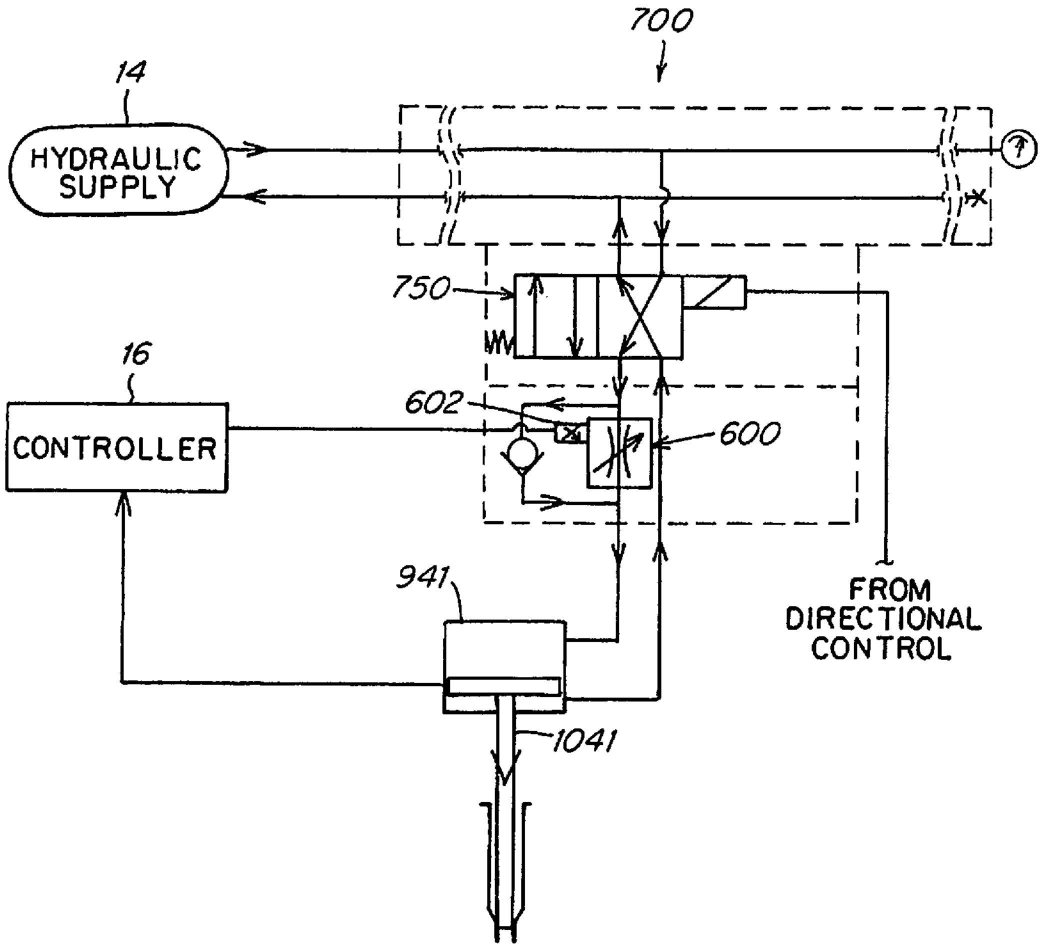

700
14
HYDRAULIC SUPPLY
750
16
602
600
CONTROLLER
941
FROM DIRECTIONAL CONTROL
1041

Fig. 2B

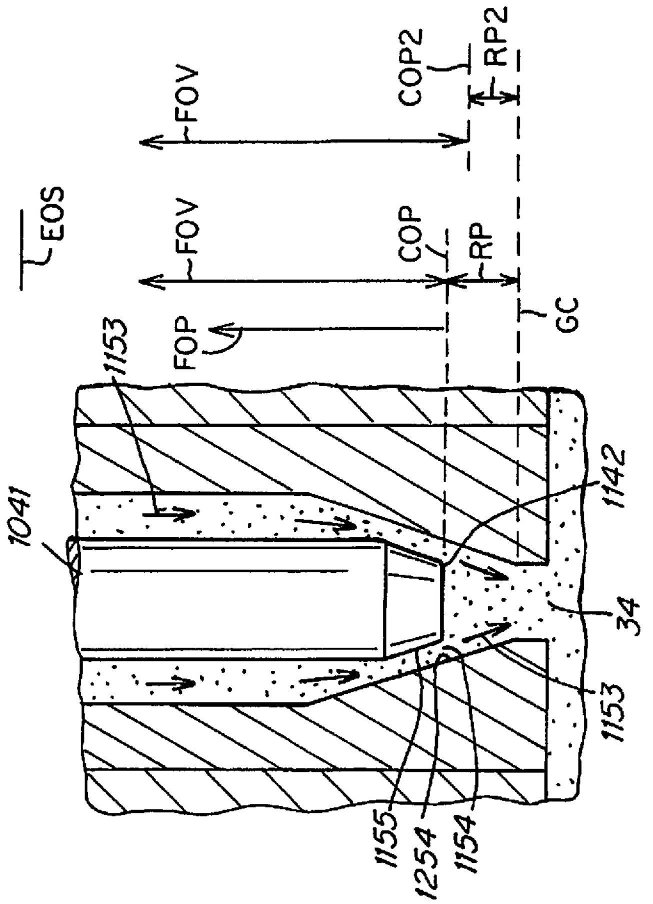

EOS
FOV
COP2
RP2
FOV
COP
RP
FOP
GC
1153
1041
1142
34
1153
1155
1254
1154

Fig. 3B

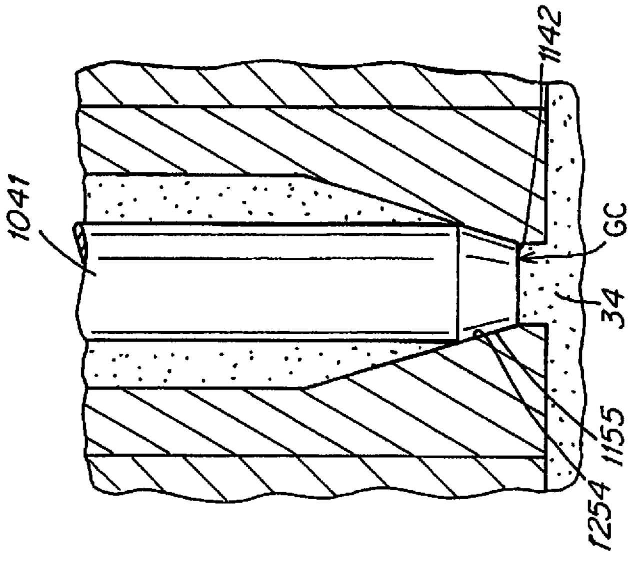

1041
1142
GC
34
1155
1254

Fig. 3A

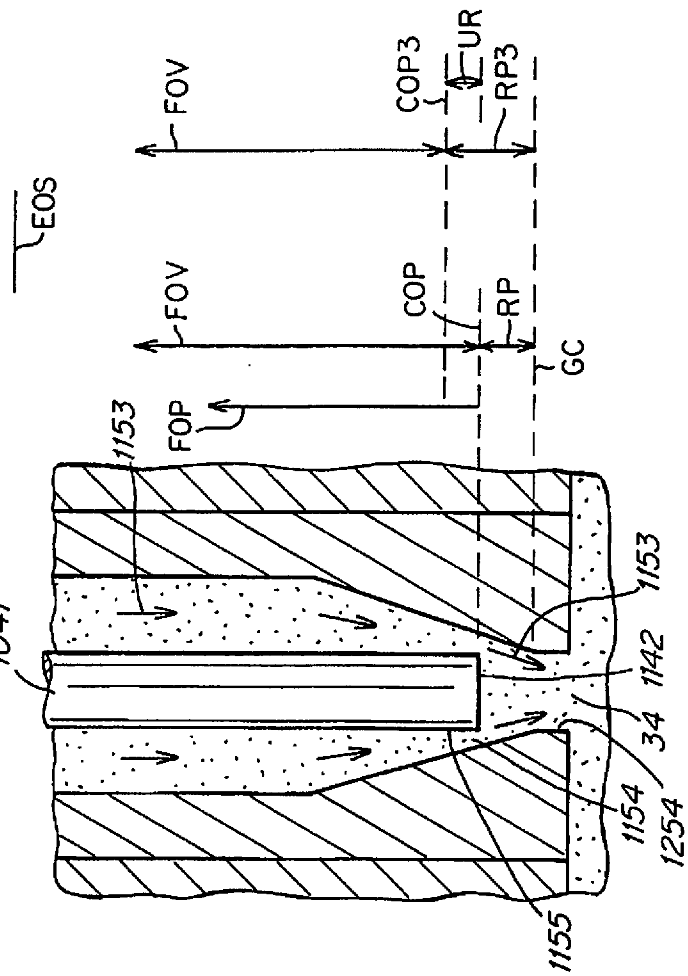

EOS
FOV
COP3
UR
RP3
FOV
COP
RP
GC
FOP
1153
1041
1153
1142
34
1154
1254
1155

Fig. 4B

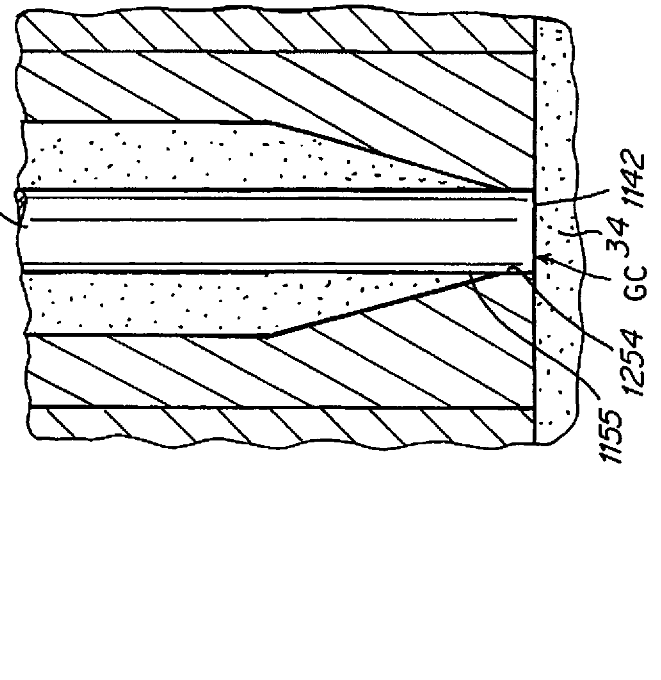

1041
1142
34
GC
1254
1155

Fig. 4A

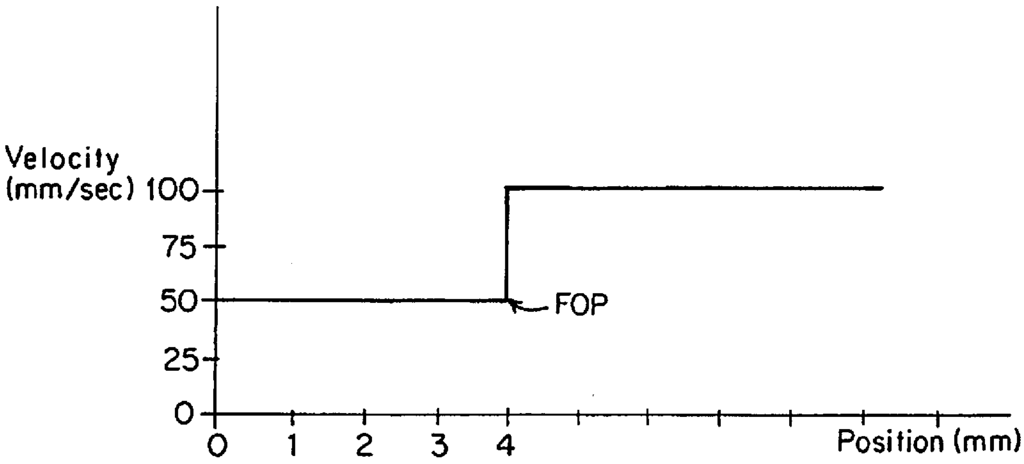

Velocity
(mm/sec)
100
75
50
25
0
0
1
2
3
4
FOP
Position (mm)

Fig. 5A

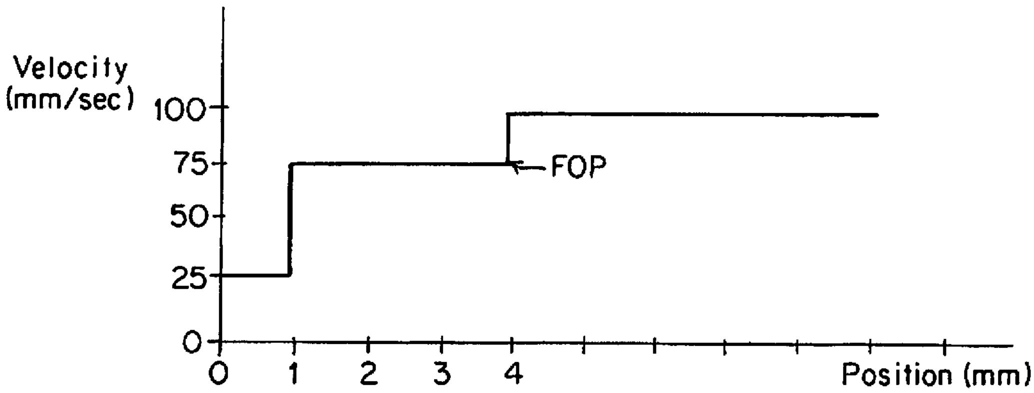

Velocity
(mm/sec)
100
75
50
25
0
0
1
2
3
4
FOP
Position (mm)

Fig. 5B

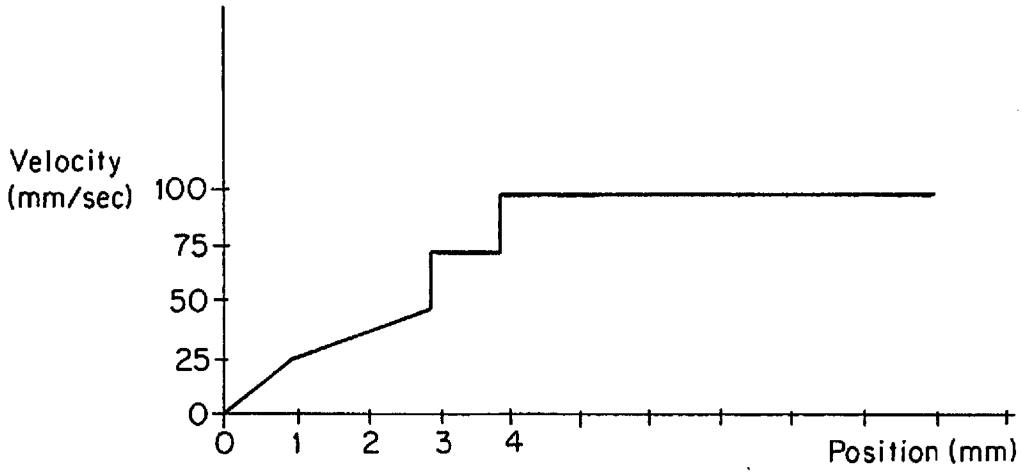

Velocity
(mm/sec)
100
75
50
25
0
0
1
2
3
4
Position (mm)

Fig. 5C

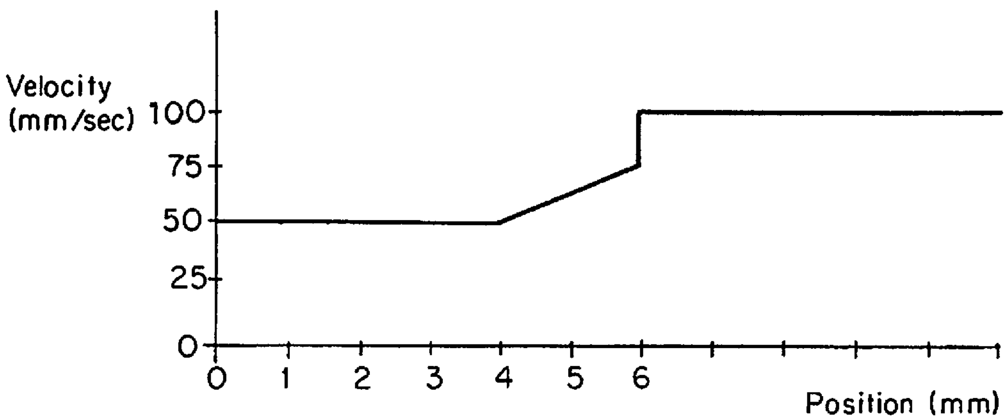

Velocity
(mm/sec)
100
75
50
25
0
0
1
2
3
4
5
6
Position (mm)

Fig. 5D

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/065611

A. CLASSIFICATION OF SUBJECT MATTER
INV. B29C45/77 B29C45/76 B29C45/28
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B29C

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014/153330 A1 (SYNVENTIVE MOLDING SOLUTIONS [US]) 25 September 2014 (2014-09-25) paragraphs [0073] - [0078]; figures 1-9 -----	1-8
X	WO 2015/066004 A1 (SYNVENTIVE MOLDING SOLUTIONS [US]) 7 May 2015 (2015-05-07) paragraphs [0045] - [0052], [0062], [0066]; figures 1-5 -----	9-15
A	WO 2012/074879 A1 (SYNVENTIVE MOLDING SOLUTIONS INC [US]; DEOLIVEIRA ANTUNES SERGIO RIBEI) 7 June 2012 (2012-06-07) paragraphs [0064] - [0074], [0088], [0089]; figures 1-5 -----	1-15

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 March 2017	30/03/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Horubala, Tomasz

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/065611

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KAZMER D ET AL: "MULTI-CAVITY PRESSURE CONTROL IN THE FILLING AND PACKING STAGES OF THE INJECTION MOLDING PROCESS", POLYMER ENGINEERING AND SCIENCE, BROOKFIELD CENTER, US, vol. 37, no. 11, 1 November 1997 (1997-11-01), pages 1865-1879, XP000776243, ISSN: 0032-3888, DOI: 10.1002/PEN.11837 the whole document -----	1-15

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/065611

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			WO 2012087491 A1	28-06-2012