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(54) IMPROVEMENTS IN/OR RELATING TO INJECTION MOULDING
 MACHINES

(71) We, EASTMAN KODAK COMPANY, a Company organized under the Laws of the State of New Jersey, United States of America of 343 State Street, Rochester, New York 14650, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to injection moulding machines and to a method of so moulding.

An object of the present invention is the provision of an improved injection moulding apparatus.

A further object of the present invention is the provision of an improved method of injection moulding.

According to the present invention there is provided an injection moulding machine for moulding articles and including a plurality of mould assemblies continuously movable along an endless path, each mould assembly having a pair of mating die members relatively movable between a closed condition in which they define a mould cavity and an open condition in which they allow removal of a moulded article, a respective injection chamber for each mould assembly and in communication with the respective mould cavity through a sprue opening, each injection chamber having associated therewith a ram for forcing cohesive fluent moulding material therein into the respective mould cavity, means for supplying moulding material in a cohesive fluent state sequentially to the injection chambers, and means for causing continuous movement of the mould assemblies and injection cham-

bers on the one hand relative to the means for supplying moulding material on the other hand.

The invention will be described further, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a perspective view, broken away of a preferred embodiment of an injection moulding apparatus incorporating the present invention;

Figure 2 is a vertical diametrical section of the injection moulding apparatus illustrated in Figure 1;

Figure 3 is a diagrammatic plan view of the injection moulding apparatus illustrated in Figure 1;

Figure 4 is a front elevation view, partially in section, of a single mould assembly with the mould cavity closed;

Figure 5 is a view, partially in radial section, of a single mould assembly with the mould cavity open;

Figure 5a is a similar view of a modified single mould assembly;

Figure 5b is a vertical section of part of an injection ram of the mould assembly of Fig. 5a,

Figure 6 is a view, similar to Figure 5, of a single mould assembly with the mould cavity closed;

Figure 7 is a plan view of a single mould assembly;

Figure 8 is a plan view of the extruder nozzle;

Figure 9 is a side view of the extruder nozzle;

Figure 10 is a schematic diagram of the hydraulic circuit for a single mould assembly; and

Figure 11 is a diagram of the operating cycle of the moulding apparatus according to

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a preferred embodiment of the present invention.

Referring now to Figures 1, 2 and 3 for an overall view of the continuous injection moulding apparatus of the present invention arranged for the moulding of thermoplastic articles, it generally includes a stationary base assembly 10 and a movable rotor assembly 11 arranged for horizontal rotation about the base assembly. A thermoplastics material extruder 12 is disposed adjacent the outer periphery of the rotor assembly 11 and is arranged to supply molten thermoplastics material to the die cavities carried by the rotor assembly, in a manner which is more thoroughly described hereinbelow. A finished article removal conveyor 13 is disposed substantially tangentially to the periphery of the rotor assembly and is arranged to receive the moulded articles as they are ejected from the moulds.

The stationary base assembly is formed of a base plate 14 and a substantially vertical, generally cylindrical wall member 16 extending upwardly therefrom. An inner bearing ring 20 is supported at the upper end of the cylindrical wall member 16 and cooperates with bearing member 22, e.g. rollers or balls, which in turn mate with an outer bearing ring 24 on the inner periphery of the rotor assembly. A vertical standpipe 26 is arranged substantially in the centre of the stationary base member and extends above the upper end of the cylindrical wall member 16. The standpipe is comprised of an outer pipe 28 communicating with a high pressure plenum chamber 30 at the upper end thereof, and a coaxial inner pipe 32 terminating in an intermediate pressure plenum 34 at the upper end thereof. Each of the plenums, 30 and 34, is arranged for rotation about the respective stationary pipes and are provided with the necessary rotary seals in a manner well-known in the art.

A rotor drive motor 36 is mounted on the base plate 14 outside of the cylindrical wall member 16 and is coupled through a variable speed transmission 37 to a vertically disposed drive shaft 38. The drive shaft is mounted to the outer surface of the cylindrical wall 16 of the stationary base assembly bearing blocks 39 and is provided with a drive pinion 40 at the upper end thereof. A hydraulic pump 41 is also mounted on, or adjacent to, the base plate 14 and is arranged to receive hydraulic fluid *via* line 42 from a reservoir 43 formed in the bottom of the base assembly, and to supply it at high and intermediate pressures *via* lines 44 and 45 to pipes 28 and 32, respectively, of the standpipe 26.

The base assembly is provided with a plurality of spaced support pedestals 46 which position and support circular, stationary cam members 47 and 48, which extend about the

periphery of the base assembly. The cam members are preferably positive acting on the cam followers to assure that the required operations are performed as will be more thoroughly described hereinbelow. Rotor brake actuators, comprising a vertically acting hydraulic cylinder 49 and a brake pad 50, are also supported on the pedestals 46. The operation of the brake actuators is also described hereinbelow.

The movable rotor assembly 11 comprises a substantially circular rotor member 51 which is preferably formed of a plurality of plates welded together into a substantially unitary structure having generally cylindrical inner and outer surfaces 52, 54, respectively. The inner surface of the rotor member is disposed substantially co-extensive with the outer bearing ring 24 to which it is connected, thereby rotatably supporting the rotor assembly on stationary base assembly 14 through bearing members 22. The outer periphery of the outer bearing ring 24 is provided with a plurality of teeth 56 forming a ring gear which engages and is driven by the drive pinion 40.

The outer peripheral surface 54 of the rotor assembly is provided with a plurality of radially outwardly extending mounting plates 58 to which the mould assemblies 60 are removably attached by means of a plurality of mounting bolts, not shown. Each mould assembly 60, which will be more completely described hereinafter, is mounted to the outer periphery of the rotor member in a manner which assures that mould assemblies are mounted equidistant from the rotor axis and at the same elevation from the apparatus base plate 14. Moreover, adjusting means (not shown) is provided for each mould assembly so that any variations in the accuracy of the dimensions of the rotor member 51 or the individual mould assemblies may be accommodated.

The rotor member 51 is arranged to support and transport a plurality of substantially circular hydraulic manifolds 62, 64 and 66 disposed about the inner periphery thereof. Also, a pair of cooling fluid manifolds 68 and 70 are disposed about and supported by the inner periphery of the rotor member. Hydraulic manifold 62 is arranged to receive hydraulic fluid under high pressure from the high pressure plenum 30 *via* connecting lines 72, while manifold 64 receives an intermediate pressure hydraulic fluid from plenum 34 *via* lines 74. Manifold 66 is arranged to discharge the hydraulic fluid returning from the mould assemblies 60 to the hydraulic reservoir 43 formed in the bottom of the stationary base assembly *via* pipe 76. The cooling fluid inlet manifold 68 is connected *via* line 80 to a cooling fluid inlet plenum 82 which is arranged to rotate in a fluid-tight manner about a centrally dis-

posed pipe 84 suspended over the standpipe 26 in the stationary base assembly. The cooling fluid outlet manifold 70 is connected via line 86 to an outlet plenum 88 which is arranged to rotate about a coaxial water outlet pipe 90 disposed coaxially about inlet pipe 84.

A horizontally disposed annular ring member 92 extends around the lower outer periphery of the rotor assembly 51 and forms a brake ring which is engaged by the brake pads 50 upon the actuation of the brake cylinders 49 quickly to bring the rotor assembly to a stop.

Referring now to Figures 4 to 7, an individual mould assembly 60 is illustrated in greater detail. The present injection moulding apparatus is illustrated with forty-eight mould assemblies 60 disposed about the outer periphery of the rotor member 51. The mould assemblies are substantially identical so that a description of only one is sufficient for an understanding of the present invention.

Each mould assembly 60 comprises a generally C-shaped assembly base member 110 having a generally T-shaped horizontal cross-section. The centrally disposed vertical rib 111 on the rear face of the assembly base member adds strength and rigidity to the overall assembly and permits the components on the front face thereof to be cantilevered outward from the assembly base member without requiring vertical support members between the components at the outer peripheral face. Thus, free access may be had between the respective components from the outer periphery of the apparatus. As previously noted, the assembly base member is bolted to the outer faces of the mounting plates 58 while the rib 111 fits into the space provided between adjacent plates.

A horizontal lower stationary (relative to the rotor member 51) mould support table 112 is arranged substantially centrally of the vertical front face 113 of the base assembly and extends radially outwardly therefrom. The lower mould support table is arranged to locate and hold a stationary female mould die member 114 therein. The female mould die member is provided with a die cavity 116 in the horizontal upper surface thereof which is substantially co-planar with the upper surface of the support table. Two substantially cylindrical, vertically extending injection chambers 118 are formed in the lower portion of the female die member 114 and each communicate at the upper end thereof with the die cavity 116 through a sprue opening 120 of reduced cross-sectional area. The injection chambers open downwardly through the lower surface 122 of the die member 114 and have a uniform cross-section from the sprue openings to said lower surface 122. The lower surfaces 122

of adjacent die members 114 are contiguous and coplanar so as to form a continuous annular surface. The injection chambers are preferably sized so that the combined capacity thereof is greater than the volume of plastics material necessary to form the part.

An injection ram-operating hydraulic cylinder 124 is vertically supported by a substantially horizontal platform 126 which extends outward from the front face 113 of the assembly base member 110 at the lower end thereof. The hydraulic cylinder 124 is connected to the lower ends of a pair of vertically movable injection rams 128 which are supported and guided by a bearing 130 which also extends outward from the front face of the assembly base member 110 between platform 126 and table 112. The injection rams have a cross-section substantially equal to the cross-section of the injection chambers. The rams are arranged to be moved vertically through the bearing 130 by the hydraulic cylinder 124 and are in vertical alignment with the injection chambers 118 so that, at the upper extremity of travel, the rams have a close fit therein, as illustrated in Figure 4. When the injection rams are at the lower extremity of their travel, the upper ends thereof are spaced below the lower surface 122 of the lower die member 114, substantially level with the bearing 130, as illustrated in Figure 5.

Each injection ram 128 is provided with an ejector pin 132 which extends axially therethrough. The lower ends of the ejector pins are connected to an actuating collar 134 carried by the upwardly extending piston shaft 136 of the ram-operating cylinder 124. The upper end of the ejector pin bore through the injection ram is provided with a reverse draw countersink 138 which engages the excess plastic remaining in the injection chamber after the mould cavity is filled so that the excess material is withdrawn from the injection chamber with the withdrawal of the injection ram. The upper end of the ejector pin 132 is normally spaced from the upper end of the injection ram at least the depth of the countersink. After the injection rams are withdrawn from the injection chamber the actuating collar 134 engages the upper surface of the platform 126 and stops the downward movement of pins 132 so that the excess material is released from the upper ends of the injection rams as they continue their downward movement and remains held by the pins 132 proud of the upper surface of the guide 130.

In the embodiment being specifically described each mould has a single cavity but has two injection chambers. This is because the article being produced has a large central window and the provision of two sprue openings provides improved flow in the mould cavity. It will be realized that under

some circumstances a single injection chamber and sprue opening may be provided. Also, more than one cavity may be provided in each mould assembly and in this case an injection chamber and sprue opening may be provided for each cavity. Alternatively, one injection chamber may supply two cavities through a Y-shaped sprue opening.

A vertically operating upper mould lifting hydraulic cylinder 142 is supported at the top of the front face 113 of the assembly base member 110 and is connected via the downwardly extending piston shaft 144 to a movable upper mould member 146. A male mould die 148 is disposed substantially horizontally in the lower surface of the upper mould member and is arranged to mate in moulding engagement with the lower mould die 114 to form a mould cavity therebetween. The upper mould member 146 is provided with a plurality of part-ejection pins 150 which are actuated by connecting rods 152 and collar member 154 which engages the lower surface of the hydraulic cylinder 142 to move the pins to eject the article as the mould is lifted by the cylinder, in a manner well-known in the art. The upper mould member 146 is aligned and guided in its travel between the closed and the opened positions by a pair of guide rollers 156 mounted, by means of eccentrically movable guide arms 158, to the front face 113 of the assembly base member 110. In this manner the mould members can be opened and closed accurately without requiring the use of guide pins which would extend between the mould members when they are open and would interfere with free access therebetween. The upper mould member 146 preferably contains the male die of the set of dies to simplify retention of the finished article by the upper mould so that it can be ejected downwardly onto the conveyor.

As schematically illustrated in Figures 2 and 10, each mould assembly is provided with means connecting the injection ram operating hydraulic cylinder 124 through an operating valve 160 to the intermediate pressure manifold 64 and to the return manifold 66. Similarly, means is provided connecting the mould lifting hydraulic cylinder 142 through an operating valve 162 to the high pressure hydraulic manifold 62 and to the return manifold 66. The injection ram operating valve 160 has an operating lever 164 which engages and is actuated by the stationary cam member 47 as the mould assembly is rotated about the stationary base assembly. The operating lever 166 of the mould lifting cylinder operating valve 162 is actuated by a connecting rod 168 which engages and is actuated by the stationary cam member 48.

Each mould assembly is also provided with suitable coolant chambers (not shown) about

the mould cavity which provide the necessary cooling to solidify the articles being formed therein and to maintain the mould assembly at the desired operating temperature in a manner well-known in the art. The coolant chambers are provided with suitable connections (not shown) to the coolant manifolds 68 and 70 on the inner periphery of the rotor spider member 51.

The thermoplastic extruder 12 is arranged substantially perpendicular to the periphery of the rotor assembly 11 as shown in Figures 1 and 3. The extruder is preferably a heated, rotating screw-type extruder well-known in the art. The extruder outlet is connected to the inlet of a feed plenum 170 which is shown in detail in Figures 8 and 9 and which is described in further detail hereinbelow. The feed plenum 170 is arranged to extend between the bottom of the mould support table 112 and the bearing 130 for the injection rams 128 which latter are in their lowermost positions as they pass the extruder. The feed plenum is held in sliding engagement with the lower surfaces 122 of the die members 114 and is arranged to supply molten thermoplastics material to the injection chambers 118 as they are moved therepast.

The extruder 12 is mounted at the outer end for horizontal rotation about a vertical axis whereby it can be rotated away from engagement with the rotor assembly should the injection rams 128 of a mould assembly not be withdrawn, or should maintenance considerations so require. The extruder is also mounted at the outer end for vertical movement about a horizontal axis 174, which vertical movement is controlled by a vertically operating hydraulic cylinder 176 located under the radially inner end of the extruder. This vertical motion permits the extruder feed plenum 170 to mate in sliding engagement with the lower surface 122 of the die members 114 with a predetermined force, or with a small predetermined clearance, which assures that there is no leakage of the molten plastics material at the interface between the feed plenum outlet and the lower surface of the die members. Moreover, the use of the vertically operating hydraulic cylinder 176 permits the accommodation of slight variations in the elevation of the lower surface of the die members as they move past the extruder without excessive leakage of molten plastics material at the interface.

Referring now to Figures 8 and 9, the feed plenum 170 has an inlet end 178 which conforms to and is attached to the extruder outlet. The outlet end of the feed plenum comprises an upwardly opening, substantially horizontal, elongated outlet slot 180 having a width substantially equal to the diameter of the injection chambers 118 which are

formed in the lower portion of the female die members 114. The outlet slot 180 is formed with a slight curvature conforming to a portion of the path generated by the lower end of the injection chamber 114 as the mould assembly is rotated about base member 10. The length of the feed plenum outlet slot 180 is substantially equal to the distance between similar injection chambers in adjacent mould assemblies 60, i.e. between the two leading injection chambers 118 when more than one injection chamber is associated with each mould assembly. The outlet slot of the feed plenum is supplied by a plurality of conduits 182 which have substantially equal flow areas and lengths, and are supplied by a plurality of intermediate-sized conduits 184 which, in turn, are supplied from the inlet 178 attached to the extruder outlet. The feed plenum is also provided with a plurality of electric heaters 186 which are arranged to maintain the temperature of the feed plenum and the plastics material flowing therethrough at a substantially constant temperature.

With this feed plenum construction, the plastics material flow from the feed plenum inlet to the outlet slot is substantially uniform throughout, with a substantially constant pressure throughout the length of the outlet slot. Thus, the flow rate over the entire length of the slot is substantially uniform. As a result, as the injection chambers 118 are moved past, or over, the outlet slot 180 of the feed plenum, each injection chamber is provided with a substantially constant, uniform supply of molten thermoplastics material at a uniform pressure. In the embodiment illustrated, wherein each mould assembly is provided with two injection chambers, and with the outlet slot having the length set forth above, the outlet slot will be supplying molten plastic to an area equal to the cross-sectional area of two injection chambers. Accordingly, the output required from the extruder, per unit time, is substantially equal to the volume of the injection chambers to be filled for each article to be made, multiplied by the number of injection chambers passing over the outlet slot of the feed plenum during that time. Moreover, so long as the rotational speed of the rotor assembly is constant, the output of the extruder is constant.

The part removal conveyor 13 is illustrated in Figures 1, 3 and 5 and comprises a substantially endless belt member 190 which is introduced between the open mould members, 114 and 146, at the location in the path of the rotating mould assemblies where the articles have solidified and cured sufficiently to permit the mould to be opened and the articles to be removed therefrom. The conveyor is mounted for horizontal rotation about a vertical axis 191 at one end there-

of and is arranged to extend tangentially between the open die members, as shown in Figure 5. The upper and lower surfaces of the conveyor member 190 are separated and supported in the region between the mould members by plates 192 supported between side rails 193. Thus, the conveyor occupies a relatively small portion of the space between the open die members. The upper surface of the conveyor 190 is arranged to move in the same direction, and at substantially the same speed, as the moving mould assemblies at the point where the articles are ejected from the upper male mould die 148. Inasmuch as the conveyor is moving in the same direction and at the same speed as the mould assemblies and the articles carried thereby, and since the articles are ejected downwardly from the upper die by the ejection pins 140 and are not subject to any gravitational rotating forces, the articles are positioned on the conveyor 190 for removal from the mould apparatus in a substantially uniform, predetermined orientation. The moulded articles may then be transported to the next operation-performing station with this predetermined orientation, substantially eliminating the necessity for reorientating the same before further operations may be performed thereon, or they may be uniformly packed in containers for storage or shipment without requiring reorientation. In the arrangement illustrated, the articles may be removed from the conveyor by a vertically operating article conveyor (not shown) disposed at the end of the conveyor having axis 191, or the articles may be picked from the surface of the conveyor by any suitable handling apparatus well-known in the art. The support of the conveyor for rotation about the vertical axis 191 permits the conveyor to swing aside, out of the space between the die members, should a malfunction occur in the mould lifting operation whereby a mould is not opened by the time it reaches the article removal conveyor. The conveyor may be provided with a sensor (not shown) which detects an unopened mould ahead of the conveyor location, thereby actuating a conveyor-rotation motor, not shown, or alternatively, the conveyor may be spring-loaded to the normal operating position, with the conveyor being moved aside by contact of the edge thereof with a closed mould assembly.

A schematic illustration of the operating cycle of the injection moulding apparatus of the present invention is presented in Figure 11, showing the relative positions of the occurrence of the various operations as a single mould assembly rotates 360° about the rotor axis. It will be understood that the actuation of the respective hydraulic cylinders 124 and 142 is controlled by the stationary cam members 47 and 48 moving the operating levers 164 and 166 of the operating valves 130

160 and 162. Thus, as the mould assemblies travel about the periphery of the base assembly, the valves are regulated according to the position of the respective cam member at that particular location on the periphery of the apparatus.

As a mould assembly 60 approaches the extruder feed plenum 170, the upper mould member 146 is in the lowermost position, in engagement with the lower mould member 114 with the die members 114 and 148 in mating engagement to form the mould cavity. The ejection pins 150 are in their retracted, upper position and the injection rams 128 are in the lowermost position, leaving the space between the lower support table 112 and the ram bearing 130 completely clear. Thus, the feed plenum 170 is free to engage the lower surface 122 of the die member 114. As the leading injection chamber 118 passes over the first end of the outlet slot 180 in the feed plenum, molten plastics material is fed into the injection chamber at a predetermined pressure and rate whereby the injection chamber is supplied with a predetermined volume of plastics material by the time it passes over the trailing end of the feed plenum. The same feeding procedure occurs with the second injection chamber for the mould assembly. As previously noted the injection chambers are preferably sized so that the combined capacity of the pair of chambers associated with each mould assembly is greater than the volume of plastics material necessary to form the part. As a result, slight variations in the feed rate of the molten plastics material from the extruder can be tolerated without resulting in "short shots" or incompletely formed articles and also so that an excessive supply of plastics material resulting from, for example, an injection station being closed down can be accommodated. At the same time, the feed rate of the extruder is preferably controlled so that an excess of plastic remains in the injection chamber at the completion of the injection step. Because of the viscosity of some thermo-plastic materials and the adhesion between the materials and the relatively cold walls of the injection chambers which may result, in the case of materials having a poor thermal conductivity, in the formation of a partially cooled skin, the thermoplastics material will not run out of the open end of the injection chambers in the short time between moving past the feed plenum and the introduction of the injection rams.

As soon as both of the injection chambers 118 are beyond the outer surface of the feed plenum 170, the injection ram-operating hydraulic cylinder 124 is actuated, driving the rams 128 upwardly into the injection chambers and forcing the molten thermoplastics material through the sprue openings 120 into the mould cavity. The plastics

material in the injection chambers is maintained at the injection pressure until the sprue opening or gate has solidified and then the injection rams are slightly retracted to reduce the residual pressure therein. Thus, the excess plastic in the injection chamber solidifies at a pressure low enough that there is no tendency for the plastics material to stick so that it can be readily withdrawn after it has solidified. The rams are then maintained in this position for a predetermined time sufficient to permit the remainder of the molten plastics material to solidify. As soon as the moulded article has solidified sufficiently to permit the excess plastic remaining in the injection chamber to be pulled away from the article without damaging the same, the injection ram-operating hydraulic cylinder 124 is actuated to move downwardly, pulling the injection rams 128 down out of the injection chambers 118 and, at the bottom of their travel, forcing the ejector pins 132 relatively upwardly to free the excess plastic from the upper end 138 of the injection ram. The sprue opening 120 is preferably constructed so that the excess plastics material is pulled cleanly away from the article, leaving little or no marks thereon which must later be removed, or which could disfigure it.

Means is provided to enter the space between the mould support table 112 and the injection ram guide 130 between the location on the periphery where the rams are fully withdrawn from the injection chamber and the position where the feed plenum engages the lower face of the mould, to remove the solidified excess plastics material, removed from the injection chamber by the withdrawal of the injection rams from the pins 132. This excess material removal means may simply comprise a scraper blade which extends between the table 112 and scrapes the upper surface of guide 130 to brush the pieces of excess material from the pins 132 into a collector adjacent the rotor assembly. The size of the excess material removed is relatively small, permitting the direct reintroduction thereof into the extruder inlet, thereby eliminating the necessity of regrinding the material to permit reuse thereof. To this end, means may be provided for reintroducing the removed excess thermoplastics material into the extruder slot.

As will be seen by referring to Figure 11, by this time the mould assembly has rotated through approximately 230° from the position where it first contacted the feed plenum of the plastics extruder. As the mould assembly rotates through approximately a further 45°, the mould lifting hydraulic cylinder 142 is actuated, partially lifting the upper mould 146. At this point the lifted upper mould has rotated to above

the article removal conveyor 13. The upper mould is then completely lifted, actuating the ejector pins 150 to disengage the finished article from the upper mould, dropping it onto the upper surface 190 of the conveyor. Immediately after the mould assembly passes beyond the area where the conveyor extends therebetween, the upper mould lifting cylinder 142 is actuated to close and clamp the mould ready to begin the next cycle. Instead of the ejector pins 150 operating to disengage the finished article from the mould and to cause it to drop, upon disengagement, onto the conveyor, it may be arranged, by appropriate formation of the ends of the ejector pins, that the ejector pins hold the article. Thus, after relative downwards movement of the ejector pins, the article is suspended by the pins. A fixed arm may then be provided at a required location to strip the articles off the ejector pins so that they fall on to the conveyor at a required location and with a desired orientation.

Whilst in the manner of operation particularly described above, the mould is closed and clamped prior to feeding of molten plastics material into the injection chamber, it is to be understood that advantages may be achieved, particularly with some less viscous materials, if the mould is not closed and clamped until after the molten plastics material has been introduced into the injection chamber. In this way, a hydraulic 'accumulator effect' tending to move the plastics material downwardly out of the injection chamber prior to insertion of the ram in the chamber, is avoided. Also, if the moulds are open when the material is injected into the chambers, the conveyor may be located closer to, or even above, the extruder thereby reducing, or even removing, a useless portion of the rotational cycle. Such a modification as has just been described would require a modification of the cam member 48, whereby the operating cycle illustrated in Fig. 11 is appropriately modified.

The machine constituting the preferred embodiment of the present invention utilizes a rotor assembly having an outer diameter of approximately twelve feet and incorporates forty-eight mould assemblies mounted thereon. The rotor assembly is rotated at any speed from 3 to 9 rpm by a $7\frac{1}{2}$ horsepower motor producing between 144 to 432 articles per minute, depending upon the speed of the apparatus. The hydraulic pump supplies the high pressure system with fluid at 1100 psi and the intermediate system at 625 psi. The moulds are clamped for the injection of plastic with a force of 30,000 pounds, and the plastic is injected under a force of 4,000 psi. Thus, an apparatus as above described would only require about 320 square feet of production area.

Whilst a preferred embodiment of apparatus incorporating the present invention has been described above, it will be appreciated that variations in the apparatus may be accomplished whilst remaining within the scope of the invention. For example, the extruder feed plenum has been illustrated and described as feeding vertically upwardly into the injection chambers, but it can readily be arranged to feed downwardly into the upper end of an injection chamber in an arrangement wherein the upper mould member is stationary and the bottom mould member is movable. Similarly, an arrangement, wherein either of the previously described arrangements for supplying plastics material to the injection chamber, can be utilized while moving either or both of the mould members between the closed, mould-cavity-forming position and the open position, without significantly altering the operation of the machine of the present invention. Likewise, the extruder and feed plenum may be arranged to engage the outer, radial chambers which are arranged to open outwardly through said surface.

The preferred arrangement has been described as utilizing individual mould assemblies which are removably connected to the outer periphery of the rotor assembly, but it will be appreciated that the mould assemblies can be formed as an integral part of the rotor assembly. Thus, the mould assembly base members could be eliminated with a corresponding reduction in the weight of the overall apparatus. Such a modification, however, would increase the complexity of the machining operations necessary as the mould assemblies could then no longer be individually adjusted for alignment considerations and must depend upon the maintenance of close tolerances during the fabrication of the rotor member.

The present invention has been described as embodied in a continuous injection moulding apparatus having a single operating cycle for each mould assembly during a single revolution of the rotor assembly about its axis. However, should operational considerations dictate, the present invention can be incorporated in apparatus having a complete operating cycle during a rotation of only 180° about the rotor assembly axis. This, of course, requires the use of an additional extruder and an additional article removal conveyor located substantially 180° from the location of those described in the preferred embodiment. Moreover, the cycle-operating cams would have to be modified accordingly. However, by operating the rotor at a speed greater than one-half that contemplated by the preferred embodiment, or by utilizing a material having a significantly shorter cure time, even greater production rates could be accomplished.

The specifically described embodiment is appropriate for forming articles of thermoplastics material. It will be apparent to those skilled in the art that when apparatus in accordance with the present invention is intended for use with thermosetting materials then heating means are provided in the die members to provide the necessary heat for curing the plastics material. Evidently in such cases, the cooling means described above would be omitted.

Materials which particularly can be processed with our machine are those that fall in the category of injection moulding compounds both thermoplastic and thermosetting with qualifications to the mould design to satisfy the process characteristics of these materials (i.e., the addition of heat or cooling to mould cavities, changes to shot volume/diameter relationship of transfer pot, design of gate and vents required).

Types and classes of polymeric compounds suitable for injection moulding are allyls; cellulose esters; epoxies; fluoro hydrocarbons and fluorovinylidenes; melamine-formaldehydes; nylons; phenol-formaldehydes; phenoxies; aliphatic and aromatic carbonates; aliphatic and aromatic esters; olefins; sulphones; styrenes; butadienes; urethanes; chloro hydrocarbons; vinyls, and vinylidenes; and various combinations thereof.

Preferably the properties of polymeric compounds desired for our machine are the ability to flow (at constant extruder pressures available) into the injection chamber; the ability to form a volume of plastic at the injection chamber surface with sufficient cohesion and adhesion to hold position in the chamber until the plunger or ram applies higher injection force; the ability to be injected through a gate or opening in the closed cavity and flow to the extremities of the cavity.

Modifications to the machine could be envisioned to handle materials with very high viscosity or very low viscosities by application of heat or cooling around the injection chamber or the use of a pulsating pressure device in place of the extruder which would force the more viscous materials into the injection chamber and have time to recover the volume displaced during the dwell period provided by the length of the nozzle.

The preferred extruder has been described as a continuously operating screw-type which supplies the molten thermoplastics material to the feed plenum at a substantially constant flow rate and pressure. However, it is possible to utilize an extruder having a reciprocating screw, of a type well-known in the art, which would provide an intermittent supply of molten thermoplastics material to the feed plenum. Thus, the plastics material and feed plenum would be

under pressure only at the time when the feed plenum was in communication with an injection chamber. Likewise, the extruder can be mounted for engagement of the mould assembly in a stationary manner without incorporating the rotation about the axes thereof previously noted.

The operation of the injection ram-operating hydraulic cylinder and the mould closing hydraulic cylinder have been described as controlled by the stationary cam members extending about the periphery of the base assembly. This arrangement is simple, inexpensive, substantially foolproof, and requires relatively little maintenance. Moreover, the use of mechanical cam-operated valves provides absolute timing of the functions of the mould components, being consistent with each of the moulds about the periphery of the apparatus, thus consistently making uniform, close tolerance parts. Further, the preferred control does not incorporate components which can "drift" or otherwise alter the adjustment of the timing. However, it will be appreciated that pneumatic, hydraulic or electrical components can easily be substituted for the mechanical controls described, while still remaining within the scope of the present invention. Similarly, the hydraulic system has been described as utilizing high pressure and an intermediate pressure; a single pressure system can easily be used for operating all of the hydraulic cylinders.

The injection rams have been described as incorporating ejector pins which removes the excess plastics material therefrom after withdrawal from the injection chambers. However, it will be appreciated that other apparatus can be used in place of the ejector pins to free the excess plastics material from the injection rams.

For example, the arrangement illustrated in Figs. 5a and 5b may be adopted. It will be seen that the ram 128¹ does not have a pin 132 therein. As may be seen in Fig. 5b, the upper end portion of the ram 128¹ has formed therein two undercuts 129 which extend generally radially of the apparatus as a whole. The undercuts 129 are so formed that the upper end surface 131 of the ram 128¹ is narrower in the direction circumferentially of the apparatus as whole. With this arrangement as the ram 128¹ engages the plastics material in the chamber 118, some material flows downwardly past the end surface 131 into the undercuts. After injection of material into the mould cavity, the excess plastics material hardens into a slug 133 conforming to the shape of the upper end of the chamber 118 and the upper end of the ram 128¹. As the ram 128¹ is withdrawn, the slug is carried downwardly with the ram by virtue of the engagement of the slug 133 with the undercuts 129. At an

appropriate location on the machine periphery, a stationary inclined arm would then be arranged to sweep the lugs 133 off the upper ends of the rams.

The preferred embodiment of the article removal conveyor utilizes an endless belt for removing the finished articles from between the open mould members; however, it will be appreciated that a rotating table member having a portion of the periphery arranged to pass between the open mould members can be substituted for the endless belt member. It will also be appreciated that more complex article handling conveyors can be arranged to enter between the opened mould members and to receive the articles ejected from the mould in a predetermined orientation which simplifies and expedites further handling of the parts after removal from the mould apparatus.

The invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the scope of the invention as defined in the appended claims.

WHAT WE CLAIM IS:—

1. An injection moulding machine for moulding articles and including a plurality of mould assemblies continuously movable along an endless path, each mould assembly having a pair of mating die members relatively movable between a closed condition in which they define a mould cavity and an open condition in which they allow removal of a moulded article, a respective injection chamber for each mould assembly and in communication with the respective mould cavity through a sprue opening, each injection chamber having associated therewith a ram for forcing cohesive fluent moulding material therein into the respective mould cavity, means for supplying moulding material in a cohesive fluent state sequentially to the injection chambers, and means for causing continuous movement of the mould assemblies and injection chambers on the one hand relative to the means for supplying moulding material on the other hand.

2. A machine as claimed in Claim 1, wherein each injection chamber has a supply opening for the reception of the moulding material from the means for supplying the same, and all the supply openings of the injection chambers lie in a common surface engageable by the means for supplying the moulding material and each ram is arranged for movement into and out of its associated injection chamber through the opening.

3. A machine as claimed in Claim 2 wherein each ram is movable between an extended position and a retracted position, and when in the retracted position, each ram is

spaced from its associated supply opening whereby the means for supplying moulding material may be interposed between the ram and the supply opening.

4. A machine as claimed in Claim 2 or 3 for moulding thermoplastics material, wherein each injection chamber is substantially unheated whereby excess thermoplastics material remaining therein after the mould cavity solidifies concurrently with the thermoplastics material in the mould cavity, the ram being adapted to withdraw the solidified excess thermoplastics material from the injection chamber into a region outside the supply opening.

5. A machine as claimed in Claim 4 including means for removing the excess thermoplastics material from the ram when withdrawn into the region outside the supply opening.

6. A machine as claimed in Claim 5 including means for reintroducing excess thermoplastics material removed from the ram means into the means for supplying moulding material to the supply openings.

7. A machine as claimed in any preceding Claim wherein the means for causing movement of the mould assemblies and injection chambers is arranged to rotate them about a vertical axis.

8. A machine as claimed in any of Claims 2 to 6 and Claim 7 wherein the common surface is an annular surface coaxial with the rotation axis.

9. A machine as claimed in any preceding Claim wherein the die members are relatively movable between their open and closed conditions in a vertical direction, the upper die member being arranged to retain a moulded article until it is ejected.

10. A machine as claimed in Claim 9 wherein the upper die member includes ejector pins adapted to cooperate with the moulding material in the mould cavity to hold the moulded article and movable to displace the article downwardly relative to the upper die member, and including means for disengaging the article from the ejector pins when in their downwards positions.

11. A machine as claimed in Claim 9 or 10 including a conveyor having a portion disposed in the region between the upper and lower die member in their open condition.

12. A machine as claimed in Claim 11 wherein the conveyor is disposed tangentially to the rotational path of the mould assemblies.

13. A machine as claimed in Claim 11 or 12 wherein the conveyor has an upper run drivable in the same direction as the direction of rotational movement of the die members instantaneously adjacent the conveyor and at the same speed as the speed of rotational movement of the die members, the means for disengaging the moulded article

appropriate location on the machine periphery, a stationary inclined arm would then be arranged to sweep the lugs 133 off the upper ends of the rams.

The preferred embodiment of the article removal conveyor utilizes an endless belt for removing the finished articles from between the open mould members; however, it will be appreciated that a rotating table member having a portion of the periphery arranged to pass between the open mould members can be substituted for the endless belt member. It will also be appreciated that more complex article handling conveyors can be arranged to enter between the opened mould members and to receive the articles ejected from the mould in a predetermined orientation which simplifies and expedites further handling of the parts after removal from the mould apparatus.

The invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effected within the scope of the invention as defined in the appended claims.

WHAT WE CLAIM IS:—

1. An injection moulding machine for moulding articles and including a plurality of mould assemblies continuously movable along an endless path, each mould assembly having a pair of mating die members relatively movable between a closed condition in which they define a mould cavity and an open condition in which they allow removal of a moulded article, a respective injection chamber for each mould assembly and in communication with the respective mould cavity through a sprue opening, each injection chamber having associated therewith a ram for forcing cohesive fluent moulding material therein into the respective mould cavity, means for supplying moulding material in a cohesive fluent state sequentially to the injection chambers, and means for causing continuous movement of the mould assemblies and injection chambers on the one hand relative to the means for supplying moulding material on the other hand.

2. A machine as claimed in Claim 1, wherein each injection chamber has a supply opening for the reception of the moulding material from the means for supplying the same, and all the supply openings of the injection chambers lie in a common surface engageable by the means for supplying the moulding material and each ram is arranged for movement into and out of its associated injection chamber through the opening.

3. A machine as claimed in Claim 2 wherein each ram is movable between an extended position and a retracted position, and when in the retracted position, each ram is

spaced from its associated supply opening whereby the means for supplying moulding material may be interposed between the ram and the supply opening.

4. A machine as claimed in Claim 2 or 3 for moulding thermoplastics material, wherein each injection chamber is substantially unheated whereby excess thermoplastics material remaining therein after the mould cavity solidifies concurrently with the thermoplastics material in the mould cavity, the ram being adapted to withdraw the solidified excess thermoplastics material from the injection chamber into a region outside the supply opening.

5. A machine as claimed in Claim 4 including means for removing the excess thermoplastics material from the ram when withdrawn into the region outside the supply opening.

6. A machine as claimed in Claim 5 including means for reintroducing excess thermoplastics material removed from the ram means into the means for supplying moulding material to the supply openings.

7. A machine as claimed in any preceding Claim wherein the means for causing movement of the mould assemblies and injection chambers is arranged to rotate them about a vertical axis.

8. A machine as claimed in any of Claims 2 to 6 and Claim 7 wherein the common surface is an annular surface coaxial with the rotation axis.

9. A machine as claimed in any preceding Claim wherein the die members are relatively movable between their open and closed conditions in a vertical direction, the upper die member being arranged to retain a moulded article until it is ejected.

10. A machine as claimed in Claim 9 wherein the upper die member includes ejector pins adapted to cooperate with the moulding material in the mould cavity to hold the moulded article and movable to displace the article downwardly relative to the upper die member, and including means for disengaging the article from the ejector pins when in their downwards positions.

11. A machine as claimed in Claim 9 or 10 including a conveyor having a portion disposed in the region between the upper and lower die member in their open condition.

12. A machine as claimed in Claim 11 wherein the conveyor is disposed tangentially to the rotational path of the mould assemblies.

13. A machine as claimed in Claim 11 or 12 wherein the conveyor has an upper run drivable in the same direction as the direction of rotational movement of the die members instantaneously adjacent the conveyor and at the same speed as the speed of rotational movement of the die members, the means for disengaging the moulded article



from the ejector pins being disposed adjacent the portion of the conveyor whereby the moulded articles fall onto the conveyor with substantially no relative motion, in a horizontal direction, therebetween.

14. A machine as claimed in Claim 2 or any Claim appendant thereto wherein the means for supplying moulding material includes a plenum disposable contiguously with the supply openings, the plenum having an outlet slot having a shape conforming to a portion of the path generated by the movement of the mould assemblies and injection chambers relative to the means for supplying moulding material.

15. A machine as claimed in Claim 14 wherein the outlet slot is arranged to feed material into the injection chambers through the openings, the feed plenum having a single inlet opening and a plurality of flow paths towards the outlet slot whereby substantially equal flow of the moulding material is available at all points along the full length of the slot.

16. A machine as claimed in Claim 14 or 15 wherein the slot has a length substantially equal to the distance between the openings in adjacent mould assemblies.

17. A machine as claimed in Claim 14, 15 or 16 for moulding articles of thermoplastics materials, wherein the supply means includes an extruder and the plenum is provided with heaters.

18. A machine as claimed in Claim 2 or any Claim appendant thereto wherein each mould assembly is provided with two or more injection chambers, injection chamber openings, sprue openings and rams.

19. A machine as claimed in Claim 2 or any Claim appendant thereto wherein, of each mould assembly, that die member having the injection chamber is stationary and the other die member is movable, bearing members being arranged positively to guide and align the movable die member in its movement towards the stationary die members.

20. A continuous thermoplastic injection moulding machine comprising a stationary base member, a rotor member mounted on the base member for horizontal rotation thereabout, means arranged to rotate continuously the rotor member, a plurality of mould assemblies mounted about the outer periphery of the rotor member, each of the mould assemblies comprising an assembly base member mounted on the outer periphery of the rotor member, a stationary mould member mounted on the assembly

base member and having a first die, a movable mould member mounted on the assembly base member and having a second die, the movable die arranged to mate in mould cavity forming engagement with the stationary die, means to space the dies apart with no alignment members extending therebetween, an injection chamber disposed in one of the mould members, the injection chamber opening through a sprue opening into the mould cavity and through an outer surface of the injection chamber forming means, and stationary means for supplying molten thermoplastics material to the injection chamber as the mould assembly moves past the supply means, each of the mould assemblies including a ram means arranged to force the molten thermoplastics material in the injection chamber into the mould cavity.

21. An injection moulding machine substantially as hereinbefore described with reference to and as illustrated in Figs. 1 to 5 and 6 to 11 or said Figures as modified by Figs. 5a and 5b of the drawings.

22. A method of continuous injection moulding, including the steps of feeding a cohesive fluent moulding material from a stationary single supply means at a first pressure to a plurality of injection means moved past the supply means in sequence, injecting the moulding material in each injection means at a second higher pressure into a respective associated mould cavity in a mould, allowing the moulding material in the cavity to harden prior to opening the mould, and removing the moulded article from the mould.

23. A method as claimed in Claim 22 wherein the step of feeding the moulding material to each injection means is performed when the mould cavity associated with the respective injection means is open.

24. A method as claimed in Claims 22 or 23 wherein the moulding material is thermoplastic, and including the step of cooling the mould.

25. A method as claimed in Claims 22 or 23 wherein the moulding material is thermosetting, and including the step of heating the mould.

26. A method of continuously moulding articles from a cohesive fluent moulding material substantially as hereinbefore described with reference to the accompanying drawings.

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