

ELECTRIC ACTUATOR FOR DRIVING A HOTRUNNER VALVE PIN**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims priority to U.S. Application No. 16/517,616, filed on July 21, 2019, which is hereby incorporated by reference in its entirety.

FIELD OF THE DISCLOSURE

[0002] This disclosure pertains to the use of an electric actuator for driving a hotrunner valve pin of an injection molding machine.

BACKGROUND OF THE DISCLOSURE

[0003] Injection molding systems can be categorized as either hotrunner systems or cold runner systems. In the case of cold runner injection molding systems, channels for the flow of liquid resin are provided in at least one mold part (e.g., mold half) to facilitate delivery of liquid resin to a mold cavity defined by multiple mold parts. After the cavity is filled with liquid resin, the resin is cooled and solidifies or hardens to form a solid injection molded part. The resin inside the channels of the mold part also becomes solid, forming cold runners that are generally recycled or discarded. In a hotrunner system, the channels through which the liquid resin flows to the mold cavity are defined by a heated manifold and heated nozzles that maintain the resin in a liquid state throughout the production process. As a result, cold runners are not produced, substantially eliminating recycling and waste during normal production. Additionally, hotrunner systems provide faster cycle times and higher production rates. Hotrunner systems typically reduce the amount of labor or robotics needed for post-production activities such as runner and sprue removal, discardment and recycling. Thus, although the hotrunner mold systems tend to cost more than cold runner mold systems, the overall

production costs per unit (part) can often be substantially less than with cold runner systems.

[0004] Surface defects due to shrinkage during cooling and solidification of the molded parts can be significantly reduced or eliminated when flow to the mold cavity is carefully controlled. In order to improve control of flow into the mold cavity of a hotrunner system, it is desirable to use electric actuators (motors) to regulate the valve pins that control flow from the nozzles, rather than the more conventionally employed hydraulic or pneumatic actuators. A problem with using electric motors to control flow through the hotrunners (manifold channels) is that the high temperatures at which the manifold and nozzles are maintained can adversely affect reliability, efficiency and service life of the electric motor. This problem has been previously addressed primarily by supporting the electric motor on one of the molding plates or other structure that is remote from the manifold during the molding cycle. These arrangements have generally added complexity to assembly and maintenance of the injection molding apparatuses.

SUMMARY OF THE DISCLOSURE

[0005] The disclosed valve gate assembly for an injection molding apparatus having hotrunners includes a heated manifold defining one or more resin channels for allowing flow of liquid resin from an injection molding machine, one or more hotrunner nozzles that are in fluid communication with a corresponding resin channel, and a valve pin configured for linear movement within and along a longitudinal axis of a corresponding nozzle to control flow of resin from the nozzle into a mold cavity. The valve pin is driven by an electric motor and transmission that are located on a cooling plate that is mounted on the heated manifold. This arrangement facilitates easier assembly and disassembly of the injection molding apparatus, reducing the time and expense associated with maintenance and repair of the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Figure 1 is a front elevational view of a valve gate assembly in accordance with this disclosure.

[0007] Figure 2 is a side elevational view of the valve gate assembly shown in Figure 2.

[0008] Figure 2A is a side elevational view of a variation on the assembly shown in Figures 1 and 2.

[0009] Figure 3 is a perspective view of another embodiment of the disclosed valve gate assemblies.

[0010] Figure 4 is a front elevational view of the valve gate assembly shown in Figure 3.

[0011] Figure 5 is a side elevational view of the valve gate assembly shown in Figures 3 and 4.

[0012] Figure 6 is a perspective view of a third embodiment of the disclosed valve gate assemblies.

[0013] Figure 7 is a front elevational view of the valve gate assembly shown in Figure 6.

[0014] Figure 8 is a perspective view of a fourth embodiment of the disclosed valve gate assemblies.

[0015] Figure 9 is an enlarged cross-sectional view of a portion of the gate assembly shown in Figure 2.

[0016] Figures 10 and 11 are perspective views of the motor and transmission shown in Figure 2 having modified cooling arrangements.

[0017] Figure 12 is a top plan view showing the relative positions of two motors and associated transmissions assembled on a molding apparatus.

DETAILED DESCRIPTION

[0018] Shown in Figures 1 and 2 is a valve gate assembly 10 for use in delivering liquid resin (typically a molten thermoplastic composition) from an injection molding machine (not shown) to a mold cavity 12 defined by mold plates 14, 16. The resin flows from the injection molding machine into a channel 18 disposed in a sprue bushing 20 heated by electrical resistance heating element 22 and is distributed through manifold channels 24 defined in heated (or heatable) manifold 26. The heated manifold is provided with electrical resistance heating elements 28 capable of maintaining the resin at a desired temperature that facilitates flow. The resin flows from the manifold channels 24 into an annular space 30 defined between internal walls 32 of nozzles 34 and a valve pin 36 that is linearly movable within nozzle 34 along a vertical longitudinal axis of the nozzle between an open position (shown for the nozzle on the left in Figure 1) and a closed position (shown for the nozzle on the right in Figure 1). When the valve pin 36 is in the open position, liquid resin flows into mold cavity 12. Nozzles 34 are maintained at a temperature sufficient to keep the resin in a liquid (flowable) state by electrical resistance heating elements 38. Nozzles 34 can be provided with external threads 40 on the inlet end of the nozzle which engage internal threads of a bore through the bottom of manifold 26 to provide a fluid-tight seal. The mold can define a single cavity or multiple cavities, and each cavity can be supplied with resin from a single nozzle or multiple nozzles.

[0019] An electric motor 42 (Figure 2) having a rotating output shaft 44 is mechanically linked to valve pin 36 by a smaller bevel gear or drive gear 46 that has teeth 48 that mesh with teeth 50 of larger bevel gear or driven gear 52 to convert higher speed, lower torque rotation around the horizontally oriented output shaft 44 into lower speed, higher torque rotation along a vertical axis. The driven gear 52 can be mechanically coupled to a rotational-to-linear converter 54 (e.g., a screw and nut type arrangement) to convert rotational movement into linear (up and down) motion of valve pin 36 along a vertical axis generally coinciding with the longitudinal center line of cylindrical shaped nozzle 34. Gears 46 and 52, along with converter 54 constitute a suitable or preferred transmission assembly 55 for converting rotational movement of a horizontally oriented

output shaft from motor 42 into linear vertical movement of valve pin 36. In the preferred embodiments, the gear ratio (i.e., rate of rotation of the drive shaft or gear to the driven shaft or gear) is greater than 2:1, preferably at least 3:1, and more preferably at least 4:1.

[0020] Figure 2A shows a variation on the valve gate assembly of Figures 1 and 2, wherein the top mold plate 64 is provided with a pocket or recess 63 that helps support the actuator (i.e., motor 42 and transmission). This arrangement also helps draw heat away from the motor and transmission by conduction (i.e., the pocket acts as a heat sink). More specifically, at least one of the electric motor and transmission is in thermal contact with a lower wall or surface of the cavity.

[0021] A cooling plate or block 56 having internal channels 58 for circulating a coolant fluid (e.g., water) is mounted or assembled (via spacer plate 60) on manifold 26. The cooling block and spacer plate (or adaptor plate) are entirely supported by and overlap the manifold. Preferably, cooling block 56 is spaced from manifold 26 by spacer plate 60, which can provide an air gap 62 between manifold 26 and cooling block 56, and minimize contact between cooling block 56 and adaptor plate 60. The thickness of spacer plate 60 (i.e., the distance between the top of manifold 26 and bottom of cooling block 56) can be from about 0.25 inch to about 2 inches. In general, greater thickness is preferred to better thermally isolate motor 42 from the heated manifold 26, while less thickness is desired to provide a more compact molding apparatus with overall dimensions of the apparatus remaining relatively unaffected by the novel arrangement. In certain embodiments, spacer plate 60 can be a material resistant to conductive heat transfer. For example, certain stainless steels and titanium alloys have a thermal conductivity less than 20 W/mK. Certain ceramic materials can have even lower thermal conductivity.

[0022] Cooling block 56 is located in a space generally bounded by a top mold plate 64 and an intermediate mold plate 66 that includes perimeter or side walls 65 that surrounds the manifold, cooling blocks and at least portions of the transmission and motor.

[0023] Assembly 10 also includes various lower support elements 68, dowels 70, and upper support elements 72 for facilitating proper alignment and spacing of the components of the assembly.

[0024] Shown in Figures 3-5 is an alternative embodiment 110 in which the motor 42 is arranged such that the output shaft 79 is vertically oriented and has a smaller gear 80 having teeth 82 that engage teeth 84 on a larger gear 85 to convert higher speed, lower torque rotation from output shaft 79 to lower speed, higher torque rotation of gear 85 and an associated shaft or hub 86. The transmission assembly may also include a rotation-to-linear motion conversion device 88 (e.g., a screw and nut type arrangement in which one of either the screw or nut is fixed) for converting the rotational movement of hub 86 into linear movement of valve pin 36. The assembly 110 is otherwise generally similar to assembly 10, with common or similar components having the same reference numerals as with the embodiment of Figures 1 and 2. Mold plates and other components that are not shown in Figures 3-5 can be, and preferably are, the same or similar to those shown in Figures 1 and 2.

[0025] Shown in Figures 6 and 7 is another alternative embodiment 210 in which motor 42 is arranged such that the output shaft 90 is axially aligned with valve pin 36 and directly coupled to a rotary to linear converter 92 coupled to valve pin 36 to provide a transmission assembly in which rotary output from the motor is translated into linear motion for moving valve pin 36 upwardly and downwardly with bore channel 30 of nozzle 34. In this embodiment, a single manifold channel 24 facilitates flow of liquid resin to a single nozzle 34. However, generally any number of manifold channels and nozzles can be provided, the illustrated embodiments being a relatively simple design to facilitate understanding of the concepts and devices disclosed herein. Except as otherwise noted, the components of embodiment 210 are generally similar to or identical to those described with respect to the first and second embodiments 10 and 110, with such components being numbered as in the preceding embodiments.

[0026] Shown in Figure 8 is another embodiment 410 having six motors 42 and nozzles 34. The various valve pins 36 can be driven at different velocities (e.g., $v_3 > v_2$

> v1) to deliver resin to different mold cavities or to different inlets of the same mold cavity of different rates. The individual velocities can be constant or can vary (accelerate and/or decelerate) independently. Also, the opening and closing speeds can be different at each nozzle. This ability to precisely control resin flow differently to different parts of the mold cavity can be tuned to optimize production quality and/or production rate.

[0027] As best illustrated in Figure 9, a leak protection bushing 90 defines an annular collar-like structure having a flange portion 92 that provides a seal between manifold walls 96 and valve pin 36. Bushing 90 is urged against a valve pin opening through cooling block 56 to prevent plastic fluid from leaking into the transmission (e.g., gears and/or converter). For example, a spring washer 98 can be used to urge bushing 90 against the valve pin opening. In the illustrated embodiments, cooling block 56 is supported on manifold 26 (via adapting plate 60) and supports both motor 42 and the transmission assembly. However, it will be appreciated that multiple cooling blocks can be used (e.g., a first cooling block for the transmission assembly and a second cooling block for the motor). Figure 2 shows only a single cooling block 56 disposed between spacer block 60 and the transmission assembly 55 (e.g., comprised of gears 46 and 48). However, in certain applications, it may be desirable to add an upper cooling block 56A (Figure 10), a side cooling block 56B (Figure 11) or a combination of both a side cooling block 56A and an upper cooling block 56B can be used together with the lower cooling block 56.

[0028] In certain applications, it may be desirable to use an extended or elongated motor shaft 300 (Figure 12) to create a space between the transmission assembly 55 and motor 42 to create a space that allows positioning of a second motor 42A and transmission 55A in closer proximity to motor 42 and transmission 55 than would otherwise be possible. This allows greater flexibility for positioning nozzles in the molding apparatus.

[0029] The arrangement or embodiments described herein provide a compact mold design that facilitates mounting of electric motors and transmission assemblies on the hotrunner manifold and within the space provided for the manifold by the design of

the assembled mold plates. The use of electric motors that are cooled within the space generally provided for the hotrunner manifold provides precise and reliable adjustment of the valve pin position and movement, which has advantages in terms of production rates, quality and reduced waste and damage.

[0030] The above description is intended to be illustrative, not restrictive. The scope of the invention should be determined with reference to the appended claims along with the full scope of equivalents. It is anticipated and intended that future developments will occur in the art, and that the disclosed devices, kits and methods will be incorporated into such future embodiments. Thus, the invention is capable of modification and variation and is limited only by the following claims.