We Expected No Less

PLASTICS TECHNOLOGY discusses the Repeater™ Valve and how it will change everything

A New Look at Check Valves

As seen in PLASTICS TECHNOLOGY

In the drive for injection molding quality, the influence of the non-return valve has been largely overlooked. Here are the first data on performance of a novel valve design, which could suggest changes in machines and molding techniques.

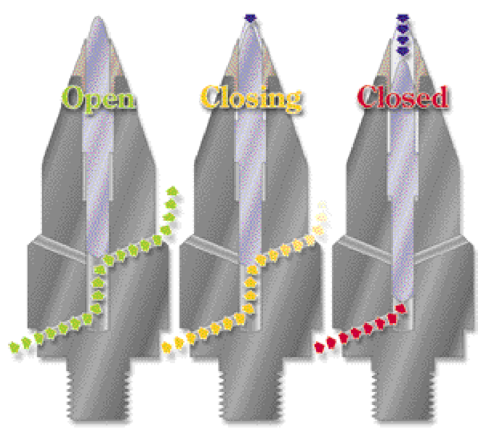
At a time when injection molded parts have grown more complicated than in years past, quality and consistency in molding those parts is becoming a paramount competitive factor in the marketplace. Statistical Process Control (SPC) is on its way to becoming a near universal necessity. Any deviation in product characteristics that can be eliminated or improved upon will certainly be required by the customer. Only the molder that can supply the lowest level of deviation will get the order.

It's no secret that one of the common, everyday obstacles to achieving the desired part-to-part consistency is the behavior of typical existing non-return valves—ring and ball-type check valves. As any molder can testify, these valves do not always close immediately at the start of injection—or even close at all on some shots. These instances of late valve closing, or non-closing, are known as "flyers".

Despite its shortcomings, the same basic check-valve technology has been used for 30 years. Injection machine and controls manufacturers have compensated for erratic valve performance by developing microprocessor-based, closed-loop control of cushion size. They have been reasonably successful, but both molders and machine suppliers may have overlooked some disadvantages in relying on cushion to make up for inherent variability in valve operation.

NEW VALVE PRINCIPLE

As reported previously in Plastics Technology, the new valve, called the *Repeater Valve,* is commercially available from U.S. Valves, Inc. in Evansville, Indiana. It differs from conventional ring and ball valves in one key respect. Ring and ball valves are closed by the action of melt flow through the valve. That is, when forward movement of the screw is initiated to start injection, some backflow of melt through the valve occurs, causing a pressure drop on the upstream side of the sliding or floating member (ring or ball). This causes the valve to close, assuming that the seats are aligned and clear of foreign matter and that valve wear does not cause leakage through sealing surfaces. With these types of valves, screw pullback is frequently used at the end of screw rotation (or sometimes at the start) to marginally increase the injection stroke and thus provide ample opportunity for the valve to close.



Unlike the 30-year-old technology valves which close by flow, the Repeater™ Valve closes via pressure. This gives the molder an amazing amount of precision and control.

The Repeater Valve, however, closes without either any melt flow through the valve or any screw movement. This valve has a central piston with a larger surface area on the downstream end than on the upstream end. This piston moves freely under the influence of differential pressure on the two ends. In other words, if the pressure on the larger (downstream) end **(P1)** multiplied by the piston area **(A1)** is different from the pressure on the smaller (upstream) end **(P2)** times the piston area **(A2),** then there will be a net force tending to move the piston in one direction or the other. Note that the valve will tend to stay closed except during screw rotation, when sufficient overpressure is generated upstream of the valve that **(P2)** × **(A2)** > **(P1)** × **(A1).**

After screw rotation ceases and backpressure is shut off (usually simultaneously), pressure will decay gradually on both ends of the piston. Since **(A1)** > **(A2)**, when **(P1)** = **(P2)**, then **(P1)** × **(A1)** > **(P2)** × **(A2).** Consequently, the valve will close.

Obviously, the greater the differential between **(P1)** × **(A1)** and **(P2)** × **(A2),** the more rapid the valve closure. Conversely, backward drift of the screw after rotation stops will slow the valve closure and allow small amounts of melt backflow. If screw drift is extreme, or excessive pullback is used, then valve closure may be delayed until the start of injection. However, with the Repeater Valve, it is possible to "capture" the full, exact amount of melt metered by the screw. This is done by preclosing the valve prior to injection. All that is needed is to maintain hydraulic backpressure on the screw for one or two seconds after screw rotation ends. That will generate a higher pressure on the downstream end of the valve, immediately forcing it closed. Tests at both an American and an European machine manufacturer showed that control programs of existing equipment can readily be changed to incorporate delayed backpressure cutoff.

Even if the valve is not preclosed prior to inject, it should be apparent that the valve will close very quickly upon initiating the forward stroke of injection. Since the length of piston travel necessary to close the valve is very small, the time required to close the valve, and thus the amount of backflow leakage, will be far less than with other valves. Most important, the amount of leakage will be consistent, as **this type of valve is not vulnerable to the "flyer" phenomenon.** The right-angle closing action of the piston eliminates problems of improper valve seating. And any slight wear that may occur on the upstream end of the piston will not affect its ability to close promptly, since there is ample overtravel of the piston.

NEW VALVE'S ADVANTAGES

The Repeater valve's closure-by-pressure feature is unique, as backflow is no longer an inherent and necessary aspect of valve closure. With preclosing of the Repeater prior to injection, **backflow can be virtually eliminated.** The only system that can perform comparably is a costly melt-accumulator system.

As noted above, wear is no longer a threat to consistent valve closing. The only moving part in the Repeater is the piston and **its sliding surfaces are not contacted by plastic flow.** In other valves, sealing surfaces are constantly in contact with polymer flow. With abrasive filled materials, erosion of those surfaces does affect valve performance. Also, sealing areas in ring and ball valves are constantly exposed to any contaminants in the melt stream that may hinder effective valve seating.

IMPLICATIONS FOR PROCESS CONTROL

Scientific testing of one machine variable or component, such as a check valve, requires eliminating or minimizing the effects of all other relevant variables. We have not come close enough to accomplishing this in testing the Repeater.

Obviously, there are many major sources of process variations in injection molding, including the plastic material itself, part and mold design, mold-temperature control, and mold clamping force. However, our primary interest is in the injection unit. The foregoing discussion has highlighted some of the most important variables there, including screw design, recovery speed and backpressure, melt residence time, and last but not least, shot volume.

Obtaining precisely consistent shot volume is one of the most complex aspects of the process, and itself can be broken down into a number of factors. One is the necessity of obtaining a precisely consistent position and pressure at start of injection. Unlike water or hydraulic oil, plastic melts have widely varying degrees of compressibility. This compressibility is evidenced by the screw "bounce-back" effect often seen when hold pressure is released, as well as the smaller initial bounce-back seen when screw backpressure is released at the end of recovery. Thus, to inject a precise amount into a mold, it is important to start injection at a precise position and pressure and with no voids in the accumulated melt.

For best control one must:

a. Stop screw rotation at a precise position. Avoid variations due to the response time of the machine control.

b. Avoid screw pullback. Avoid mold designs that require pullback to prevent mold drool. Pullback through an open non-return valve introduces voids in the accumulated shot and allows inconsistent flow through the valve. Avoid non-return valves that require pullback to improve their repeatability.

c. Compensate for position drift after stopping screw rotation. In addition to bounce-back when recovery backpressure is released, the screw often drifts backward. This is probably due to continuing decay of the pressure profile along the screw established during rotation. As the pressure decays, flow occurs both toward the feed throat and forward into the accumulated shot as pressure equalizes. Maintaining recovery backpressure—or better, maintaining position control after "Stop Rotate"—will avoid this drift. However, many (probably most) machine hydraulic systems and control systems require modification to accomplish this.

d. Obtain a repeatable pressure at the injection starting position. As noted above, plastic compressibility makes this necessary for precise shot-size control. This is not easy to achieve with current technology. Valves used to control recovery hydraulic backpressure are often inaccurate and inconsistent in operation at these low pressures. Further, variations in viscous resistance to movement between the plastic-filled screw and the barrel, along with seal and piston-ring friction in the screw-drive system, mean that low hydraulic pressures do not translate efficiently into control of plastic pressure. Therefore, closed-loop control of melt pressure in the shot chamber will probably be required. Once a repeatable injection starting position and melt pressure have been achieved, the Repeater's preclosing feature will effectively "trap" that precise amount of melt so that none escapes back through the valve prior to or during injection.

A second major priority, as we have seen, is to close the non-return valve reliably and without variation. All conventional non-return valves have significant leakage flow out of the accumulated shot during valve closing, at the same time that flow is starting into the mold. Ring and ball valves are usually—but not always—quite consistent in the amount of accumulated shot weight that "escapes" before the valve closes. Both lab and production data show that **the Repeater is much more consistent,** due to the small plunger motion required to close, and its dependency on pressure only (no escape flow is required) for closing action. **No test of the Repeater has ever shown a "flyer"** such as has been seen even under laboratory conditions with ring valves.

Just as important as a repeatable injection starting position and pressure is to stop injection at a precise forward position and pressure. Bottoming the hydraulic cylinder at a controlled pressure accomplishes this. Most modern machines can provide the needed pressure control.

We strongly believe that preclosing the non-return valve will be the way of the future to improve control of the injection molding process. The preclosing must be done at a precisely controlled position and plastic pressure. Closed-loop control of pressure at valve closing will probably be required. Cushion, the crutch for valve performance and lack of position and pressure control, can then be eliminated. Screw design, mold-temperature control, and plastic material consistency will then become the major variables in the molding process.

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