Retrofitting Molded Part Quality

Control Technology. By using variotherm mold temperature control, processors are able to meet today's demanding requirements for surface quality and injection molded part accuracy. Temperature control circuits operating in parallel, increase not only product quality, but also process efficiency. Implementation of such a concept requires accurate control technology and short response times.

Fig. 1. Solenoid-operated proportional valves, available in nominal sizes from 0.05 to 20 mm, can eliminate very small temperature fluctuations through precise valve corrections

Fig. 2. Paddle wheel sensors detect flow rate changes very quickly and can be used as standard components or incorporated into customer-specific block solutions for temperatures up to 160 °C

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Many branches of industry expect no less than warp- and stress-free parts with excellent dimensional stability and a perfect surface today. The automobile and consumer goods industries are the driving force behind these requirements: for instance, headlight lenses and flat screen televisions have especially demanding requirements regarding surface appearance. At the same time, the efficiency of the injection molding process represents a focal point: about 70 % of the cycle time is determined by the time to cool the molded part alone. Accelerating the process thus increases efficiency immediately. Reducing the cooling time without compromising molded part quality, however, requires sophisticated cooling technology for injection molds.

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Variotherm Mold Temperature Control with Conformal Cooling Channels

With variotherm mold temperature control, the mold temperature does not remain constant, but rather is varied intentionally during the injection cycle to provide a defined temperature profile. At the moment of injection, the mold temperature is approximately as high as the stock temperature. Following this, the mold is cooled intensely. In this way, it is possible to produce plastic parts with a high-gloss surface, but without any deformation or flow marks. At present, the following variations of variotherm temperature control are being employed:

- heating through use of steam,
- heating by means of oil,
- induction heating,
- heating with the aid of infrared emitters and
- electrical heating based on use of heating elements,

each in conjunction with liquid cooling. Implementation of these dynamic processes requires a conformal arrangement of cooling channels in order to heat and cool quickly. Moreover, the different zones associated with heat removal from

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Fig. 3. The multi-channel block contains the flow rate sensor, temperature sensor and solenoid-operated control valve

molded part on the basis of different wall thicknesses must also be taken into account.

The more cooling channels there are in the mold and the closer they are to the cavity, the more accurately the cooling process can be controlled – with one prerequisite: each cooling channel must have its own temperature controller. New mold techniques such as "segmented mold temperature control" [1] or LaserCusing [2] make it possible to incorporate such three-dimensional cooling channel structures in the mold. This even makes it possible to resolve the contradiction posed in part by variotherm mold temperature control and requirement for short cycle times.

For accurate temperature control when injection molding, the mean cavity wall temperature must be measured, either directly in the mold close to the cavity or indirectly from the temperature of the coolant return line. Usually, thermocouples or resistance thermometer (e.g. Pt 100) are used for this purpose. They transmit the measured values to a controller that regulates the flow of coolant to each individual cooling channel. This as-needed cooling and the alternating introduction of hot and cold media require high-performance sensors and valves. For such tasks, Christian Bürkert GmbH & Co. KG, Ingelfingen, Germany, offers ready-to-use solutions.

Valves for Controlling the Slightest Temperature Fluctuations

Control of several temperature control circuits simultaneously became possible only with development of new solenoid-operated proportional valves. The unique feature of the proportional valve lies in its friction-free support of the magnetic core by specially designed springs that prevent stick-slip effects. This is reflected in the operating data such as high responsiveness (0.1 % of final value), less hysteresis and exceptional control quality. The span of the new solenoid-operated proportional valves is 1:100. Applied to the process, this means that the ratio of the lowest to the highest flow rate can be varied over a range of 1:100. As a consequence, even extremely small temperature fluctuations can be eliminated by very precise valve corrections (Fig. 1).

The decisive control variables are the temperature of the coolant return line and the flow rate of the returning water. They determine the cooling of the injection molded part and regulate the supply cooling precisely and reliably. The return line temperature must be measured separately for each cooling channel, which requires one valve and one temperature sensor per channel as a minimum. To improve the dynamics of temperature control, the flow rate and the supply temperature must be known. Modern sensors detect changes in the flow rate within 0.1 to 0.3 s. Control valves correctly flow rate within 0.3 to 1 s. Because of their small size and exceptional dynamics, paddle wheel sensors have proven to be especially well-suited for such applications (Fig. 2). If it is necessary to measure the flow rate without any moving parts, magnetic-inductive sensors and ultrasonic sensors are available.

Which Valve under What Conditions?

The valves selected depend on the flow rate and the amount of contamination in the cooling water. In the case of high flow rates and highly contaminated water, use

Fig. 4. Electropneumatic control valves with minipositioner are available in nominal sizes from 4 to 15 mm

of direct-acting valves is recommended. Up to 180 °C, pneumatically actuated valves designed as on/off or control valves are best-suited. On/off temperature control or pulse cooling during the cooling phase of the injection molding cycle is commonly employed if the open time of the valve is controlled as a function of the amount of heat to be removed.

In the case of low flow rates and very clean cooling water – e.g. when central water treatment is provided – and water temperatures of up to 90 °C, pilot-operated electromagnetic valves are ideal. These can be used without difficulty for nominal sizes of up to 20 mm. The new generation of on/off valves functions without a pilot-hole in the diaphragm and can be used even if the cooling water becomes contaminated.

For multi-channel temperature control, where different amounts of cooling are required because of the part design, electromagnetic (Fig. 3) or pneumatic control valves – regardless of whether direct-acting or pilot-operated – offer a definite benefit. Their stroke can be varied steplessly between any value from 0 to 100 %. This dynamic capability permits use of pre-programmed temperature profiles tailored to the particular molded part. The stepless temperature control is gentle on the valve, extending its service life. Furthermore, in the case of pneumatic valves, the nominal size is not restricted by the pressure of the liquid. It can range from 4 to 20 mm and higher. Setting a specific valve stroke is accomplished through use of additional electronics. On solenoid-operated proportional valves, pulse width modulation (PWM) is employed for this; on conven- ▶

Benefits of the Process

Variotherm mold temperature control
- prevents weld lines,
- provides distortion- and stress-free parts,
- ensures high-gloss surfaces on conventional as well as foamed injection molded parts,
- displays no traces of glass or carbon fibers on the surface when processing reinforced plastics,
- facilitates ejection of thin-walled parts,
- shortens the cycle time when molding thick-walled parts,
- improves the homogeneity and ultimate strength of molded parts.

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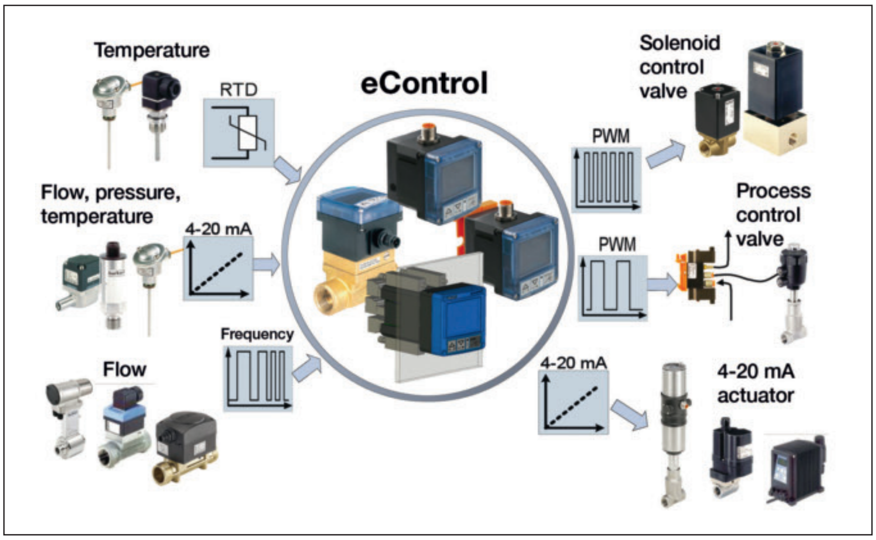

Fig. 5. The eControl 8611 universal controller is capable of processing a variety of sensor signals such as temperature, pressure or flow rate and actuate both pneumatic and electric final control elements (photos: Bürkert)

tional process valves, a positioner is used (Fig. 4).

Local Temperature Control

The usual temperature control loop consists of a temperature sensor and a proportional valve. To increase the temperature control dynamics, a flow rate measurement (paddle wheel, ultrasonic or magnetic-inductive) is required in addition. In combination with a proportional valve and a temperature/flow rate controller, any flow rate profile can be provided. The controller functions as the link in the system with all of the possible valve and sensor combinations. It must be capable of processing a variety of sensor signals such as temperature, pressure or flow rate and actuate both pneumatic and electric final control elements. The eControl universal controller developed by Bürkert specifically for use in cooling systems provides all of these capabilities (Fig. 5).

Decentralized control offers significant benefits. The sensor, valve and controller are matched to one another, the central machine controls do not have to handle secondary control tasks. In addition, decentralized temperature control simplifies retrofitting to existing equipment: In the manner, injection molders can shorten the cooling phase and improve molded part quality noticeably without a great deal of effort or expense. ■

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2 LaserCusing ermöglicht konturnahe Kühlung in Werkzeugkernen und -einsätzen. MM Das IndustrieMagazin, Nr. 45/2007

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