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But it Does Move

Controlling the Melt Front

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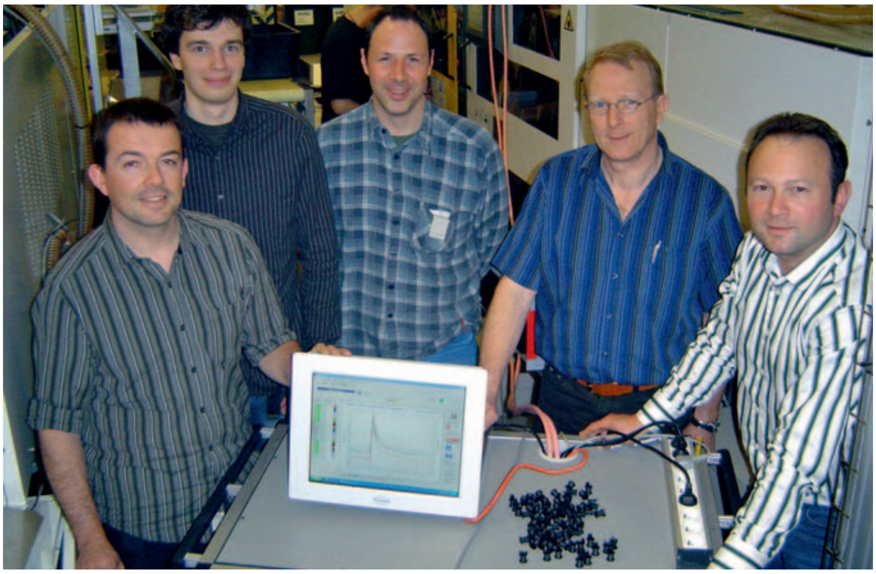
Special reprint

Controlling the Melt Front. One effective and simple way to control parts quality in injection molding is to measure cavity temperature. The precise position of the melt is always known – which is not the case when cavity pressure is measured – and this brings a number of advantages with it.

But it Does Move!



Jan Schotte, Bram Vandecasteele, Raf De Saeyer, Piet Graus and Alex Soenen (left to right) of Tyco Electronics Belgium. The reject rate dropped dramatically after introducing automatic switchover based on cavity temperature (Figures: Priamus)

CHRISTOPHERUS BADER

Today's economic structures are creating big problems for processors. Automating the injection molding process is often the key to saving on material, shortening cycle times or reducing the amount of rejects. Automatic control of the melt front enable not only significant improvements in product quality, but also safeguard process handling by a small number of trained employees. The technological background for this is provided by the intelligent use of cavity temperature signals which, in many cases, offer serious advantages over measurement via cavity pressure.

A Common Misconception

The significance of the switchover to holding pressure continues to be underestimated in actual practice. Yet there is hardly a simpler and more efficient way to reduce variations in the quality characteristics of molded parts than to optimize this step. In saying so, we have to do away with a common misconception: The most constant machine setting possible isn't what leads to the desired consistency in mold part weight or dimensions – quite the opposite is the case.

The classical switchover methods are based on screw position or cavity pressure. They use a permanently set switchover threshold optimized during mold setup with a filling series at zero holding pressure. The goal here is to switchover to holding pressure at the highest possible volumetric filling. However, once the mold has gone through set-up and its switchover point has been determined, that machine setting can no longer be changed without undergoing another series of fillings for optimizing it, since any change in injection speed necessarily alters the injection volume. That is why the switchover position and/or switchover pressure have to be reset.

There is a similar connection between constant machine settings and natural variations in melt viscosity, such as occur due to batch variations, when regrind is processed or due to the influence of dampness. In other words: Every process variation in injection molding alters melt flow behavior and, at permanently set switchover thresholds, leads to greater or lesser deviations. When the variations are extreme, this leads to unfilled cavities or overfilled parts.

Automatic Switchover to Holding Pressure

By contrast to cavity pressure sensors, cavity temperature sensors detect a sud-

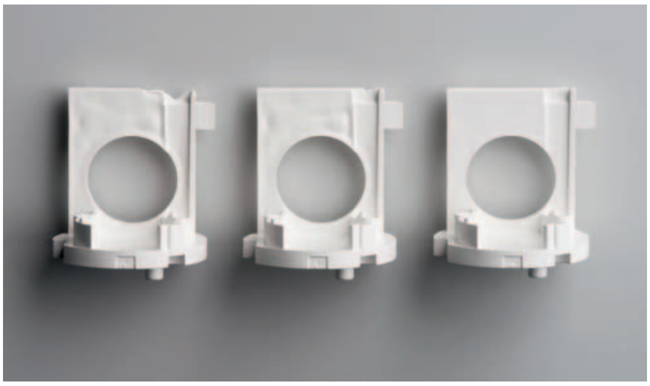


Fig. 1. When the automatic holding pressure switchover was optimized, delay times were varied between 15, 30 and 45 ms

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den temperature increase within milliseconds – i. e. the arrival of the melt at the position of the sensor. For automatic switchover to holding pressure, they are located just ahead of the end of the flow path. Via a method patented by Priamus System Technologies AG of Schaffhausen, Switzerland [1], a switch signal is immediately generated that the injection molding machine uses to switch over to holding pressure automatically.

Switching over to holding pressure automatically eliminates the need to optimize with filling tests, since the melt front is always recorded independently of machine settings. It even compensates changes in the machine setting, e. g. injection speed, and the resulting changes in melt volume. Thus mold setups and process optimization are considerably more robust, less subject to problems and easier to handle than by the classic procedure. Natural variations in the melt and ambient conditions are automatically compensated, thus clearly reducing the range of variation in the weight and dimensions of molded parts.

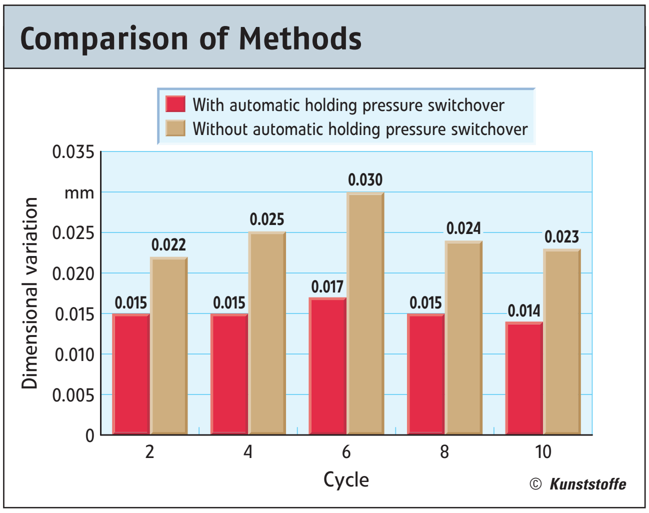

Fig. 2. The dimensional variation among molded parts (from Fig. 1) is smaller with automatic switchover than with conventional methods

Two practical examples can illustrate this point: Wild & Küpfer AG of Schmerikon, Switzerland, has compared various switchover techniques over a longer period of time – with the following result: In cases where a cavity temperature sensor cannot be located at the most favorable position, the switch signals can be optimized with the aid of delay times (Fig. 1). Dimensional variations in the injection mold parts turn out much smaller during mold setup (Fig. 2), both in terms of deviation as well as variety when the Priamus switchover method is used rather than the conventional switchover methods [2].

The electric plug manufacturer, Tyco Electronics Belgium EC N.V. of Oostkamp, Belgium, used to have problems when processing glass fiber reinforced materials (PPA-GF33), especially with variations in dampness content and consequently with viscosity. Since automatic switchover compensates viscosity variations, it enables them to eliminate the sorting of parts by hand (Title photo). By the conventional method, 5 to 10 % was the usual percentage of rejects, whereas with automatic switchover, over 600,000 were produced without a single reject. Noticeable variation in screw position at the point of switchover was observed as a logical consequence of this method.

The Opening and Closing of Shut-off Nozzles

In injection molding, detecting the melt front in real time is of great significance, not only for automatic switchover to holding pressure, but also for many other applications. Only when the melt position is actually known, can it be utilized for regulation and control functions. This is hard to do by measuring cavity pressure, since a certain pressure has to be built up before the switchover point is reached – i. e., before sending a signal for the shut-off nozzle to open or shut. It takes time for this point to be reached during which the melt proceeds over an unknown distance (Fig. 3). The position of the melt at the point of switchover is

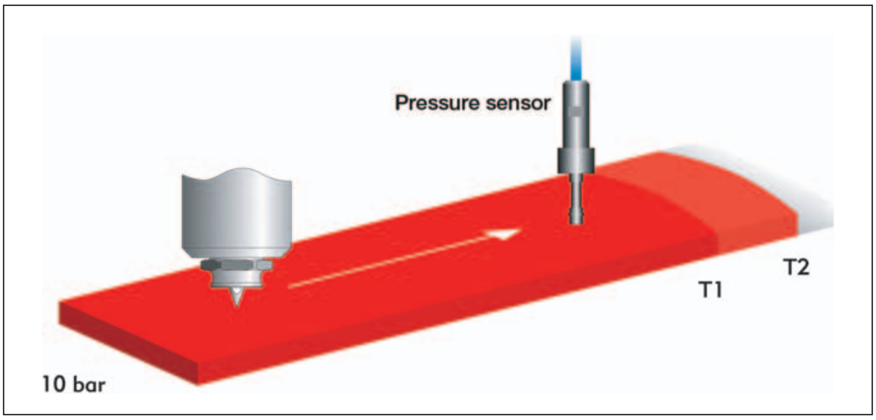

Fig. 3. Having reached the cavity pressure sensor, the melt continues to flow until a definite pressure threshold has been reached due to flow resistance (T1). If the viscosity varies, the melt front (T2) automatically shifts position while the pressure threshold remains unchanged. Thus the position of the melt front is unknown

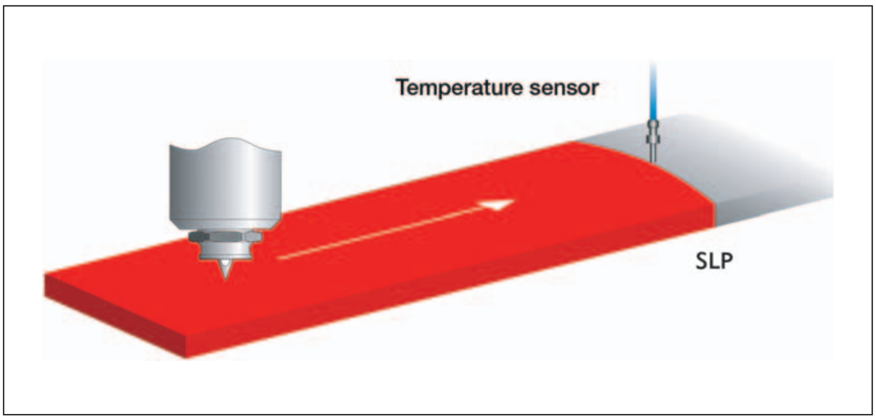

Fig. 4. The melt front reaches the cavity temperature sensor and is detected immediately via increased temperature. The position of the melt front is known and can be utilized for control purposes

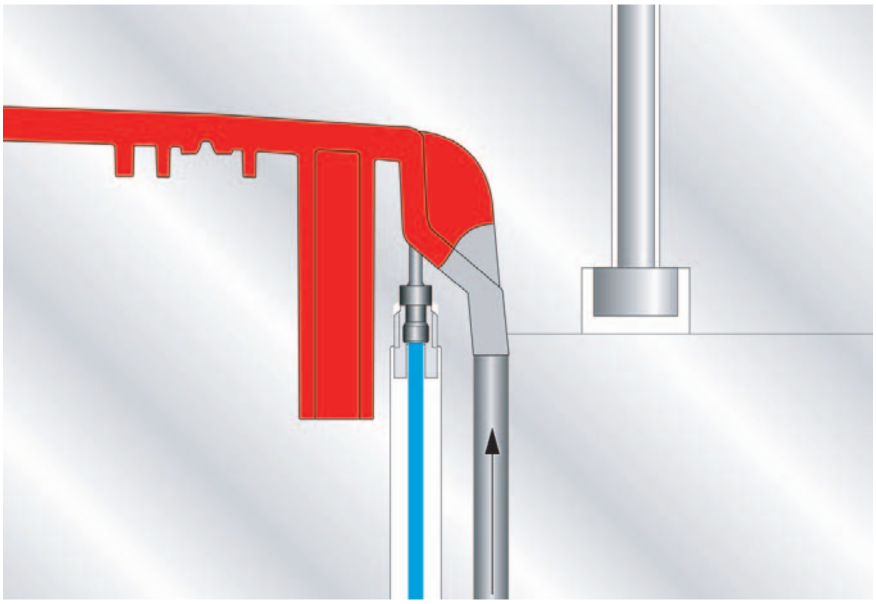

Fig. 5. Automatic ventilation: A cavity temperature sensor detects cavity filling and initializes venting core closing

thus not known. Since pressure does not build up uniformly during production, but varies according to the actual ambient conditions and variations in melt viscosity, the opening or closing of shut-off nozzles always takes place at different melt positions when linked to this pressure level.

A cavity temperature sensor detects the melt front automatically (Fig. 4). When the melt reaches the sensor, the temperature rises quickly, so that the position of the melt is always known regardless of ambient influences or alterations of viscosity. Thus shut-off nozzle opening and closing can be regulated and above all, automatically, by a switchover signal generated either when the sensor position is reached, or by using delay times. This method can have practical applications, e.g. for detecting, moving and regulating weld line positions, for automatically opening shut-off nozzles in sequential injection molding [3] or for ventilating cavities automatically via an automatically triggered venting core (Fig. 5).

In many cases, it is not possible to predict the exact melt position or the end of the flow path due to complex parts geometry. It is also possible for the melt position to shift due to various machine settings. In family molds, for example, it is often impossible to make all cavities fill simultaneously. For such cases, the Priamus electronics can release a switchover action on either the first or the last signal (Fig. 6 on the right). Depending on the application, this makes it possible to prevent the parts from overfilling ("first signal") or ensures that all parts or zones are completely filled ("last signal").

Application	Description	Cavity pressure	Cavity temperature
Automatic holding pressure to switchover	Automatic detection of temperature increase	no	yes
General process optimization		yes	limited[1]
Viscosity monitoring	Detection of viscosity via pressure and temperature sensor	yes	yes
Viscosity control	Flow front control for cold runners	no	yes
Hot runner balancing of multi-cavity molds	Automatic control of hot runner nozzle temperatures	limited[2]	yes
Control for core pullers	Switchover signal dependent on melt front	no	yes
Sequential molding control	Opens and closes shut-off nozzles	limited[2]	yes
Sequential molding control	Controls flow rate	no	yes
Weld line control	Shifts and keeps weld lines constant via reference control	no	yes
Weld line control	Shifts weld lines via automatic switchover signal	no	yes
Control of mold surface temperature	Automatic tempering control (shrinkage control)	no	yes

[1] Optimization of injection speed
[2] Control not possible via flow front

Table 1. Comparative overview of various control and optimization methods based on measurement via cavity pressure vs. cavity temperature (Priamus has applied for and, in part, been granted patents on all procedures with the exception of overall process optimization)

Balancing and Controlling the Hot Runner

Hot runner molds with one or more cavities are subject to natural variations caused by changes in ambient influences as well as by differences in mold tempering or melt viscosity. That is why injection molded parts necessarily differ in consistency, weight and dimensions [4]. This affects, among other things, the plane parallelism of particular geometries (Fig. 7). Without active hot runner control, there are natural limits to the precision of any process. The hot runner can be controlled by automatically detecting the melt position in the cavity and adapted via the nozzle temperatures in the hot runner. If the nozzle temperature is too low at a particular cavity or a particular zone of a broad surface part, the melt flow path is reduced. By analogy, the flow path lengthens at too high temperatures. Both errors are systemat-

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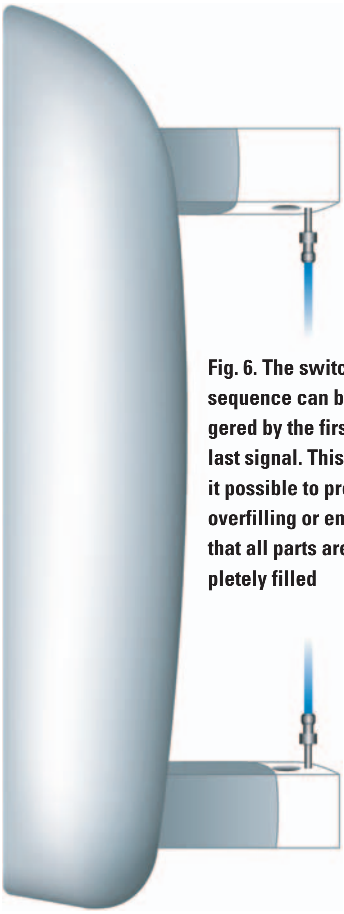

Fig. 6. The switchover sequence can be triggered by the first or the last signal. This makes it possible to prevent overfilling or ensure that all parts are completely filled

ically detected and automatically corrected.

The original idea for this control method goes back to the mid-Nineties, when for the first "baby-steps", cavity pressure was used – instead of cavity temperature sensors. The functionality of the method could thus be demonstrated in the simple case of a multi-cavity mold with identical cavities. To be sure, this principle had clear limitations: Hot runner balancing was thus based on a pressure increase which, by contrast with cavity temperature, is not transformed into a signal prior to the compression phase, i.e., long after filling and switching over to holding pressure. Thus control based on melt position is impossible when cavity pressure sensors are used. Many applications, such as melt flow control in car bumpers, or when processing fluid silicon cannot be implemented without knowledge of the actual melt position (Table 1).

Molded parts shrinkage, and with it the final dimensions, depend largely on mold tempering and temperature distribution on the mold surface. These parameters in turn can only be detected and regulated by cavity temperature sensors. Priamus' system "Fill & Cool" enables both the balancing and control of a hot runner system, as well as automatic control of mold temperature.

Uniform Molded Parts Thanks to Hot Runner Control

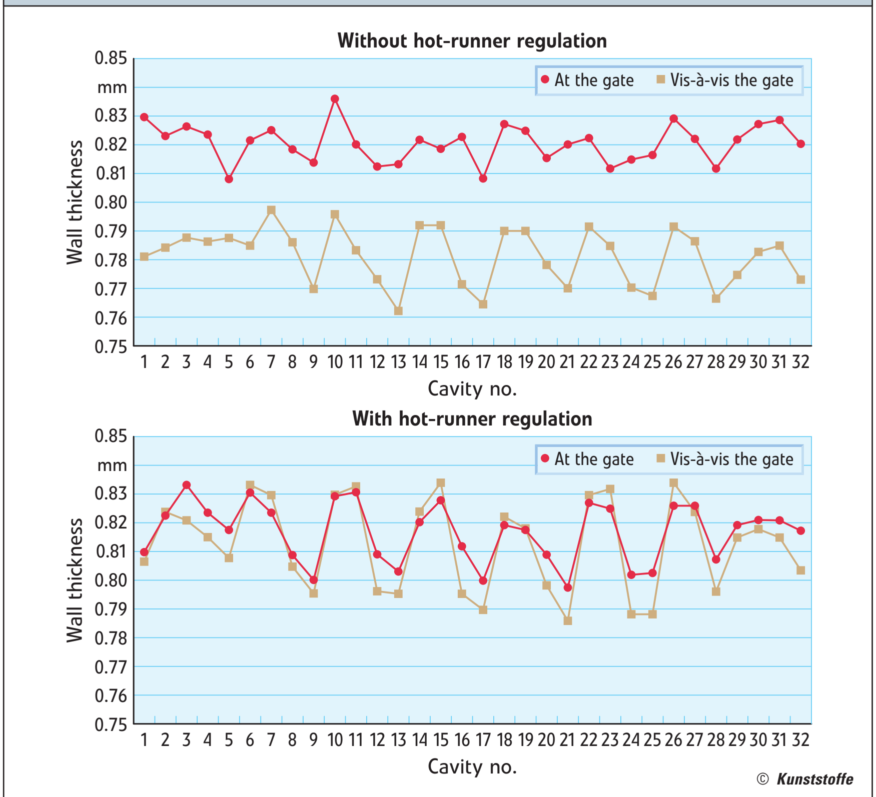

Fig. 7. Wall thickness variations in a medical-technical part among 32 cavities without (above) and with hot-runner regulation (Priamus Fill & Cool, below)

Economic Considerations

The reworking of molded parts at Wild & Küpfer runs up annual costs that amount to several times what it costs to produce them. In such a case, automatic holding pressure switchover and a Priamus Fill & Cool system will pay for themselves in less than half a year. To be sure, the costs incurred by retrofitting can make up a considerable portion of the total purchase price, depending on the manufacturer.

Tyco Electronics, Belgium, has been producing approx. 12.5 million parts annually with a reject rate of 5 to 10%, whereby the rejects were sorted out by hand. Assuming a reject rate of 5%, the total annual cost for rejects including material, machine time, energy expense, etc., amounts to EUR 168,500. Utilization of automatic holding pressure switchover alone has enabled them to manufacturer over 600,000 parts to date without a single defective part. The investment paid for itself within three months.

Outlook

Control based on the melt front offers great potential for automating and optimizing the injection molding process. The precondition for this is the quick and sure detection of the melt front in the cavity, as well as intelligent signal processing. Although the signal from cavity pressure is excellent for purposes of optimization and monitoring, it is unsuitable for melt-front based control, for various reasons. By contrast, control systems based on the measurement of cavity temperature have demonstrated their potential in many hundreds of applications worldwide. ■

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