Hot Runner Balancing Enters Production

Proven Method for Automatic Balancing of Multi-Cavity Hot Runner Molds with Standard Connection to Industry 4.0-Systems

Competitive advantages and growing cost pressures are behind the relentless drive to keep raising production line output. The key elements for achieving this are multi-cavity mold designs, such as can be realized with stack and cube molds. The growing demands on processes, especially those involving high numbers of cavities, can be met by using smart control systems that deliver consistently high product quality, even under fluctuating input conditions.

The "Quality Balancer" system being used in the production of a cover for an ESP housing (© Priamus)

A basic requirement of multi-cavity molds is that the cavities must deliver parts of identical quality, yet it is not always an easy one to meet, especially with high-end molded parts. For, as the number of cavities increases, so too the process and the mold become more demanding. Simultaneous filling of all cavities is critical, because unbalanced mold filling will lead to variable part quality even within the same shot. The possible consequences otherwise are variations in part weights, differences in dimensions and strengths, over-filled and under-filled parts, different surfaces, and warping. Controlling the process by conventional means takes so much effort that, when undesirable process changes occur, some considerable time may elapse before remedial action is taken. When random samples are taken for statistical analysis – as opposed to monitoring every part in every shot – bad parts often go undetected.

Partly Disagreement over Balancing Fundamentals

In this context, it is essential to clearly define what is meant by uniform balancing, because even experts continue to start out from different assumptions, some of which are false. A multi-cavity mold is balanced when all cavities are filled with the same volume of molding compound at the same time [1]. Only then does the changeover point suit all cavities equally – and not just a few. This changeover point is reliably and efficiently indicated by the readings from heat sensors that are installed in the mold walls at the end of the flow path and detect the arrival of the flow front by virtue of a rise or fall in temperature (the latter, for example, occurs in the case of LSR) [2].

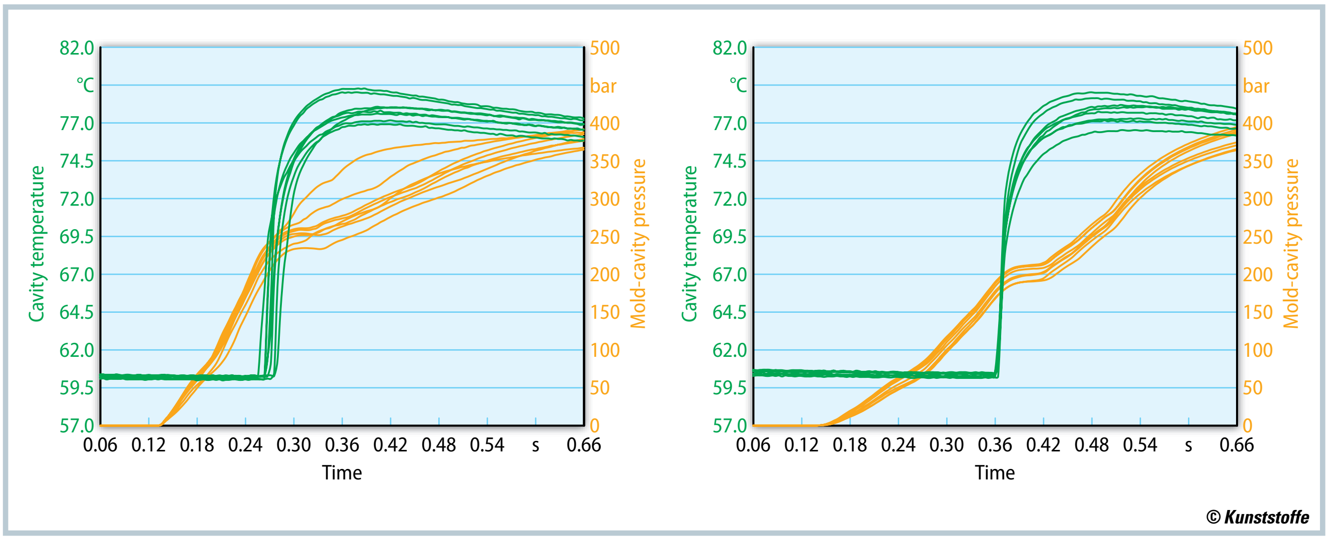

Fig. 1. Whereas the time offsets between the cavity pressure signals at various pressure levels differ in both the unbalanced (left) and the balanced states (right), there is virtually no time offset for the temperature rises in the balanced state (source: Priamus)

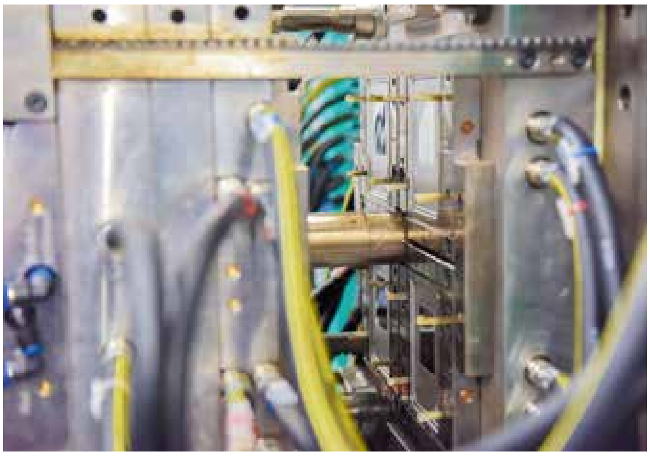

Fig. 2. View inside the stack mold. The rack and the melt guide tube are clearly visible (© Priamus)

The sensors eliminate the need for elaborate fill studies, which are not possible in the case of very small parts anyway. Such studies are mostly only conducted for sampling purposes and for dealing with serious problems. The crucial point here is that detection occurs during the filling phase. In contrast, the use of pressure sensors to monitor pressure thresholds in cavities exploits only the compression phase, and thus occurs at a later point in time when the molding compound has stopped flowing.

Until a few years ago, cavity pressure was the focus of all activities relating to molded part quality, but it is now known that molding is a multi-dimensional process which is comprehensively described by the PVT behavior and so depends on a number of parameters. Thus, adds a quality dimension to theory that can be put to practical use. For instance, the same cavity pressure will not automatically translate to the same fill volume if the temperature and the viscosity vary. And that is continually the case due to are fluctuations in material, material compounding, ambient conditions and temperature control in barrels, manifolds, nozzles and molds.

Priamus System Technologies, a branch of Barnes Group Suisse Industries LLC, is regarded as a pioneer in the automatic balancing of multi-cavity hot runner molds and other process controls [3]. Since 2001, this Schaffhausen, Switzerland-based company has been using systems that incorporate cavity temperature sensors for automatic flow front detection, during which time it has accumulated a wealth of technological expertise thanks to the many systems operating on the market. Its experience has been that cavity pressure thresholds during the compression phase are not conducive to good balancing in the case of demanding parts.

Pressure increases are characterized by time offsets at different threshold values, whereas temperature increases during the fill phase are characterized by a minimal, clear balancing time offset (**Fig 1**). The pressure threshold to select as the basis for balancing therefore remains uncertain – as a result of which balancing itself is also uncertain [4]. In contrast, numerous fill studies have shown that a temperature increase, as detected by a custom-developed algorithm during mold filling, correlates with the degree of fill and the part weight [5].

Practical Application with a Stack Mold

At Walter Söhner GmbH & Co. KG, Schwaigern, Germany, a mold for making ESP (Electronic Stability Program) housing covers from PBT-GF30 was used to conduct preliminary studies of the specific problems associated with stack molds (**Fig. 2**). The mold has only four cavities per stack, but it is still useful for studying the different control strategies. Integrated into the mold is a hot runner system (**Fig. 3**) supplied by Otto Männer GmbH, Bahlingen, Germany, a company which specializes in multi-cavity molds, including multi-cavity stack molds.

Stack molds are far superior to parting-line molds because they offer virtually twice the output for virtually the same machine footprint. This means that unit costs can be lowered substantially. However, the mechanical structure of the »

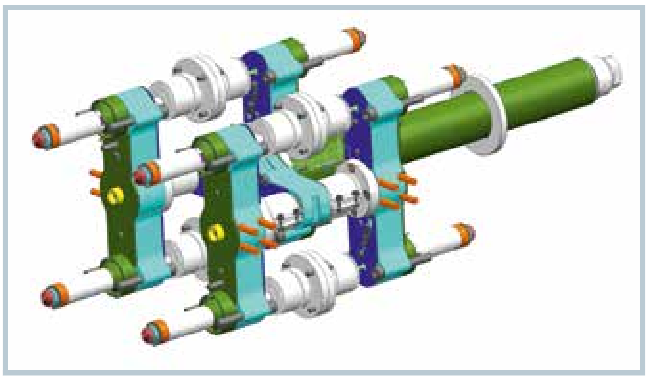

Fig. 3. 8-fold hot runner system for the stack mold with bushing, manifold and nozzles from Männer (© Walter Söhner)

center part is a potential weak point that can lead both to variations in part quality within a single shot and to increased wear. As the center part is usually not very rigid and is not supported by the clamping platens, it can deform under the influence of the clamping force and the injection pressure. This, along with process influences, can contribute to uneven mold filling.

The new "Quality Balancer" system, an entry-level version of the Fillcontrol H automatic hot runner balancer from Priamus, was used in trials to gain initial insights into stack-mold influences and to demonstrate the system's practicality. The Quality Balancer is a user-friendly control system for balancing multi-cavity hot runner molds. As was the case with the first system in this new series, namely the Quality Monitor, great importance has been attached to the integrated internet of things (IOT) options as a way to readily network real quality data.

The Finer Points of Automatic Hot Runner Balancing

To establish that the hot runner controller was suitable, a series of trials was initiated to verify and optimize the PID controllers of the G24 hot runner controller (manufacturer: Gammaflux Controls GmbH, Wiesbaden, Germany). The response of the PID controllers is a decisive factor for controlling the temperature of the nozzles and manifolds and for ensuring that automatic hot runner balancing is working properly. For this reason, it is advisable to optimize these in advance (**Fig. 4**). Were this aspect to be ignored, the heating zones would respond too slowly or overshoot by too much, and that would reduce the performance, even in a static application. Optimization is all the more important for dynamic applications, where the nozzle temperatures are continually changed to compensate for fluctuations in the process.

Standard molds with one parting line normally utilize a controller to balance multi-cavity hot runner molds. Temperature sensors positioned in the wall of each cavity at the end of the flow path detect when the melt arrives at this position. The balancing time offset is calculated and mold filling is then automatically balanced by changing the temperatures

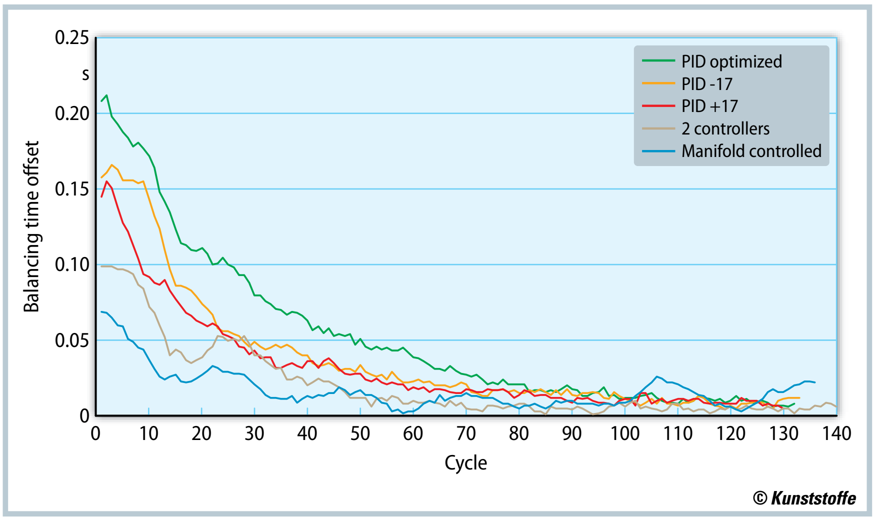

Fig. 4. Balancing with different PID parameter settings and control strategies. The diagram shows the temporal change in hot runner balancing based on the balancing time offset between the automatically determined temperature rises in the various cavities. The trend chart reveals the inertia of the various settings, with the smallest deviation representing the best possible balancing (source: Priamus)

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Companies

Priamus, like the two other companies – Männer and Gammaflux – mentioned in this article are members of the "Molding Solutions" division of Barnes Group Inc. Bristol, USA. Further partners in this integrated company are Foboha, Synventive and Thermoplay.

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Service

References & Digital Version

- You can find the list of references and a PDF file of the article at *www.kunststoffe-international.com/7157758*

German Version

- Read the German version of the article in our magazine *Kunststoffe* or at *www.kunststoffe.de* of the hot runner nozzles in line with a special algorithm.

Balancing is divided into two phases. The first transforms the mold from an unbalanced to a balanced state while the second maintains the balance at the best-possible value despite all process fluctuations. This contrasts with the subjective approach of an engineer who conducts a filling study by looking at the fill level of the molded parts and then draws on his experience to manually adjust the nozzle temperatures. Anyway, it is inconceivable that manual interventions could be made during production without changing the validated quality parameters.

Different Control Strategies

Consequently, in the first trial, one controller was specified that simultaneously balanced all the cavities in both stacks. To establish a baseline, the nozzle temperatures were adjusted manually; this yielded a balancing time offset of approx. 0.1 s. No significant fill time offsets were found between the cavities of stacks 1 and 2. With automatic balancing, the fill time offset was controlled to a stable minimum (< 0.01 s), the nozzle temperatures being adjusted within the permissible processing limits for the material. What is more, the molded parts also had the same dimensional accuracy across all test parameters, such as flatness, length and width.

Separate controllers were then specified for the two stacks, each balancing independently of the other. The Priamus system is designed for use with as many controllers as the application requires, e.g. for several components, several injection units for cube molds or cascade controls. The baseline had the same balancing time offset of approx. 0.1 s as before. This control strategy too produced a very good result, with balanced cavities and fill time offsets of less than 0.01 s and no appreciable differences in nozzle temperatures (**Fig. 5**). Again, in this trial, compliance with the specified dimensions was obtained.

The trials thus demonstrated that, regardless of the chosen configuration, optimum balancing can be achieved with stack molds as well and that the new Quality Balancer (**Title figure**) is an industrial-grade practical system that lends itself to a wide range of industrial applications. Overall, in this case, effects on the quality characteristics were less pronounced due to the glassfiber content of the polymer employed and the less demanding tolerances than would be the case for unfilled materials. On account of the small number of cavities, the mold's mechanical weak point barely made its presence felt, as would be expected otherwise with a much larger number of cavities or larger and less rigid molds.

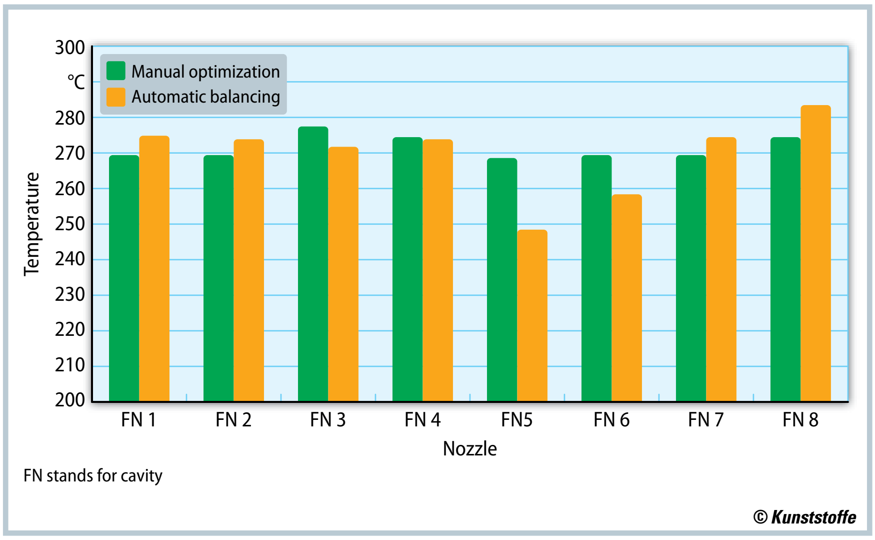

Fig. 5. While a balancing time offset of 0.1 s was recorded for manual optimization, a time offset of just 0.01 s was achieved with automatic balancing. For optimal balancing, the nozzle temperatures had to be adjusted accordingly (source: Priamus)

Conclusion

The trials form the basis for follow-up trials, already planned, on multi-cavity molds in which the low rigidity of the center part is a much more substantial problem. Due to the very high potential savings, there is growing demand for molds for sophisticated products in the medical and pharmaceutical sectors as well as in the packaging industry that are capable of high productivity in a robust process. With production-ready control systems for automatic hot runner balancing of the kind offered by Priamus today, this should be straightforward with multi-cavity stack or cube molds in the future. Just a few years ago, only the more conservative, yet cost-intensive variant featuring smaller molds would have been considered in such cases. Success will come to whoever is prepared to use new technologies in conjunction with smart mold concepts. ■

Company Profile

Services offered by **Walter Söhner GmbH & Co. KG** include the production of prototype, stack, 3-platen, hot runner and multi-component molds as well as molds for strip, rotor and stator overmolding. These are used to injection mold all conventional, non-reinforced and reinforced engineering plastics as well as high-performance plastics. The product range extends from mechanical and electromechanical components (plastic-metal connections, multi-component and assembly components) to general technical plastic parts through to plug connections and press-fit contacts. These products are employed in the automotive (e.g. climate control, safety and braking systems), energy technology (e.g. solar and wind energy), medical and general consumer goods sectors. Walter Söhner employs some 700 employees at its headquarters in Schwaigern near Heilbronn, Germany, and has manufacturing plants in the USA, China and Romania.

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