Special reprint from Kunststoffe international 6-7/2016

HANSER

Christopherus Bader

A Question of Balance

Automatic Valve Gate Control for Hot and Cold Runners

Special reprint

PRIAMUS SYSTEM TECHNOLOGIES AG
Rheinweg 4
CH-8200 Schaffhausen / Switzerland

Tel. +41 (0)52 632 2626
Fax +41 (0)52 632 2627
info@priamus.com
www.priamus.com

Masthead
Publisher: Carl Hanser Verlag GmbH & Co. KG, Kolbergerstr. 22, 81679 München

A Question of Balance

Automatic Valve Gate Control for Hot and Cold Runners

Sensor-based process controls fitted directly in the injection molding tool are becoming increasingly important. The reasons are easily explained: Even without complications, injection molding processes are continuously subjected to variations. What is more, to an increasing extent, molded parts are being produced in emerging countries, where there is a lack of qualified personnel. The obvious solution is to control the process at the point where the quality of molded parts is determined, i. e. directly in the mold.

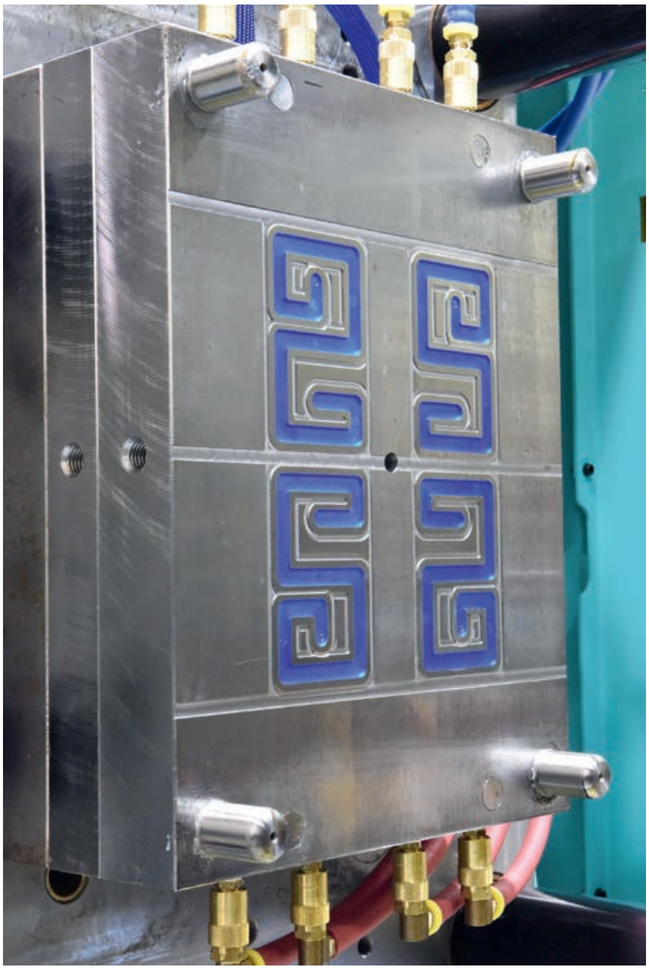
All attempts to put the control of injection molding processes back into the machine have failed because they ultimately do not determine in that location. Another aspect to be considered in this context is the high cost pressure, which ever more frequently results in the expensive checking of parts after production (post inspection) being dispensed with. A prerequisite for this is a comprehensive documentation of the quality parameters in the mold on the one hand, and their control-related adaptation on the other, if the specified limit values are exceeded. The consequence – particularly for internationally active companies – is the standardization of quality control systems in the mold.

Meanwhile, the balancing of hot runner molds by means of cavity temperature sensors is an accepted and widely used procedure in injection molding. Hereby, the melt flow in the individual cavities of a multi-cavity mold is determined, and then adapted and optimized via the corresponding nozzle temperatures [1–4].

Entirely new possibilities in the field of process control are opened up by the ability to position and control the pins in the corresponding valve gates directly as a function of melt flow. In this way, multi-cavity molds can be balanced without having to change the nozzle temperatures of hot runners. Using this principle, hot runner systems for thermoplastic materials can be balanced just as well as cold runner systems for the injection molding of liquid silicone.

The Control Principle

The advantages of valve gate nozzles are well known. As opposed to open nozzles, larger nozzle cross-sections can be used, whereby the material is subjected to less shear during the injection procedure. Moreover, active nozzle closing enables the cycle time to be optimized precisely. Several control concepts, such as the activeGate systems from Synventive Molding Solutions GmbH in Bensheim, Germany, also permit pin speed to be controlled, which results in an improved surface



4-cavity spiral mold with valve gate nozzles for testing the Priamus control system for automatic balancing via the valve gate stroke (© Priamus) quality in the gate area. Basically, however, the latest generation of valve gate controls features an interface to the valve gate controller, via which the pin stroke is specified in every cycle, thereby enabling it to be controlled precisely.

Instead of influencing the melt flow – and thereby melt viscosity – in the cavities via the nozzle temperatures, it is also possible to control melt volume via the pin stroke of the valve gate from cycle to cycle (**Fig. 1**). Prerequisite for this is a cavity

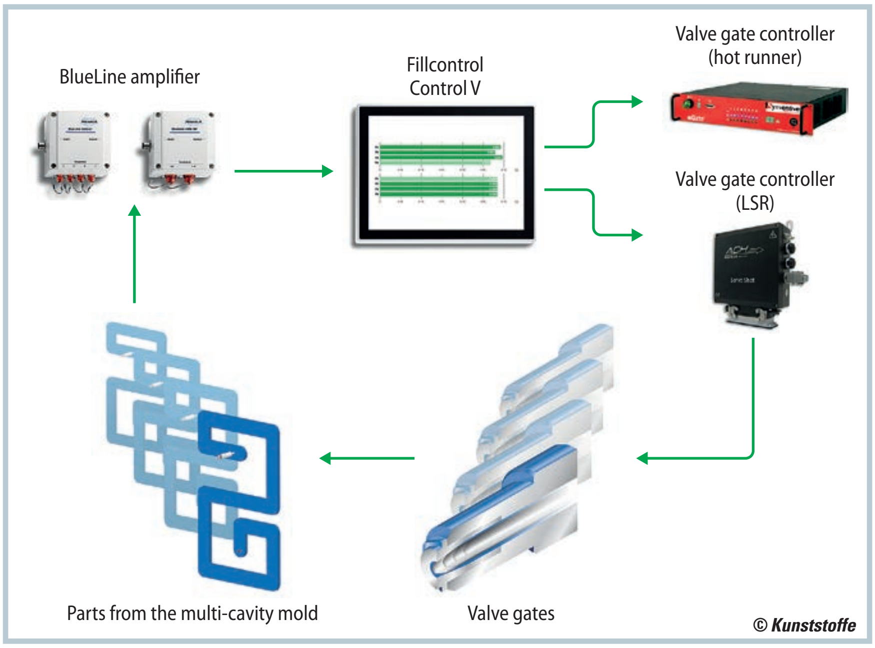


Fig. 1. From the filling differences – cycle by cycle – the Priamus system calculates the required pin stroke settings in order to obtain a balanced filling (source: Priamus)

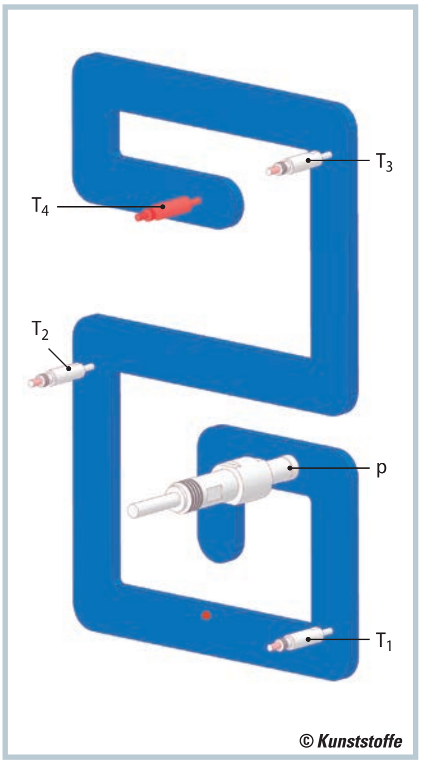


Fig. 2. One pressure sensor close to the gate, and four temperature sensors along the flow path are fitted in each cavity. The temperature sensor just short of the flow path end is used for automatic balancing via the valve gates (source: Priamus)

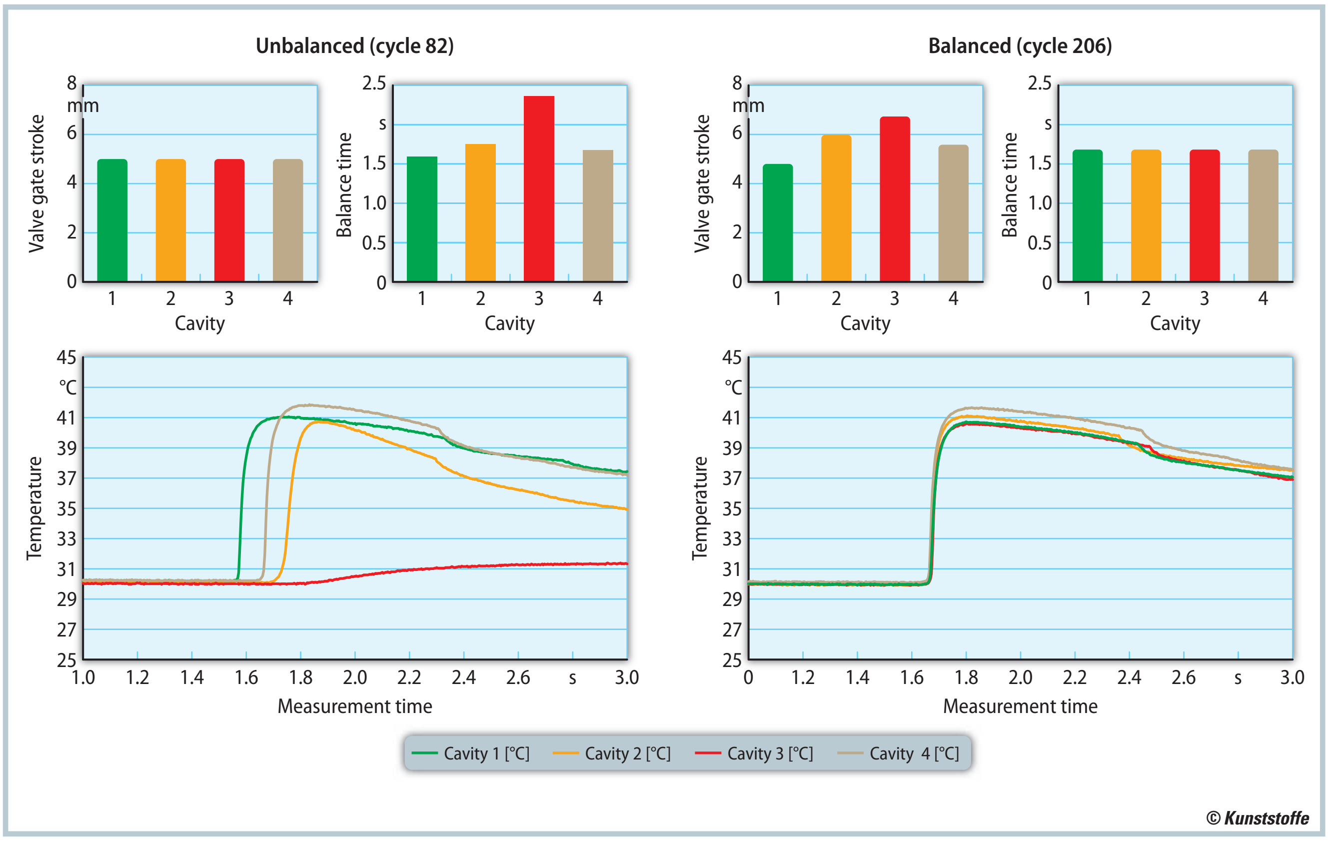


Fig. 3. With equal valve gate strokes in all cavities, the cavity filling times ("balancing times") are inevitably different (left). In the balanced state (right) filling is identical in all cavities – prerequisite for uniform quality of the molded parts (source: Priamus)

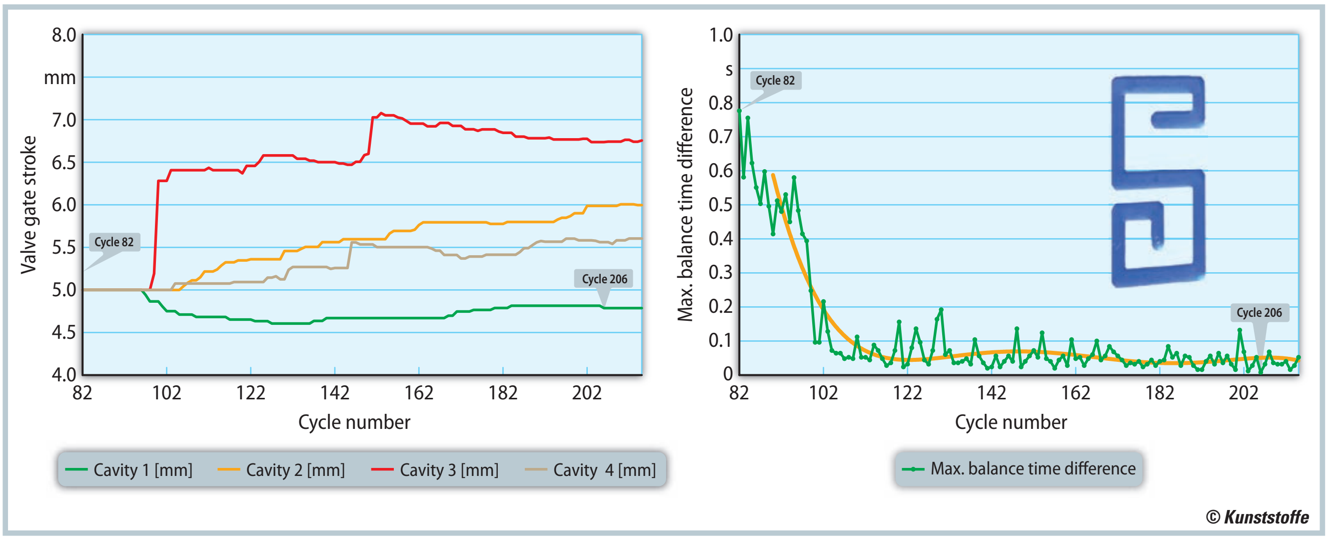


Fig. 4. The curve of the valve gate control shows that the cavity filling times are practically identical shortly after the control system is activated. Shown left is the respective pin stroke of the valve gate per cycle, and the balancing time difference on the right (source: Priamus)

temperature sensor ahead of the end of the flow path, which detects the arrival of the melt during the injection cycle practically in realtime. In a multi-cavity mold, the individual cavities are usually filled at different times, which – due to different compressions and shrinkages – inevitably results in quality variations in the molded parts.

The automatic detection of the melt front in every cavity enables the different filling times from cavity to cavity to be recognized and analyzed automatically, e.g. with the Fillcontrol Control V system (supplier: Priamus System Technologies AG in Schaffhausen, Switzerland). The Priamus system calculates the optimized settings of the respective pin stroke for every cycle, and transmits them to the valve gate controller via an interface. In this way, the filling times in every cavity are automatically matched and balanced to each other adaptively.

Automatic Valve Gate Nozzle Control in Practice

In order to test the automatic valve gate nozzle control, the hot runner specialist Synventive built a hot runner test mold at its headquarters in Peabody, MA/USA, and fitted each of the four cavities with a cavity pressure sensor (type 6002B) and four cavity temperature sensors (type 4004C; supplier of both: Priamus). Hereby, the pressure sensor and the first three temperature sensors in every cavity were used to determine the viscosity and the filling times along the flow path, and the fourth cavity temperature sensor – located just before the flow path end – was used exclusively to test the valve gate nozzle control (**Fig. 2**).

Due to their geometry, the four individual flow spirals in the mold offer ideal conditions for measurement and control of possible flow differences from cavity to cavity, and also to visualize them by means of the incompletely filled molded parts. The trials were carried out with an Allrounder 520H 1500-400 Hidrive injection molding machine (manufacturer: Arburg GmbH + Co KG, Lossburg, Germany) and a hot runner controller (type: G24-39170M; manufacturer: Gammaflux Europe GmbH, Wiesbaden, Germany). The polypropylene used (type: P4G4Z-011; manufacturer: Flint Hills Resources, Wichita, KS/USA) was mixed with a master batch (type: BL2237P; manufacturer: Color Master Inc., Butler, IN/USA).

In order to illustrate the flow differences from cavity to cavity more clearly, the settings in the trials were adjusted so that the moldings are not filled completely. In the unbalanced initial state (cycle 82) an identical valve gate stroke resulted in different filling times ("balancing times") in the four cavities in spite of the same injection volume in the valve gates (**Fig. 3**). The Priamus valve gate control automatically adapts the pin stroke in each of the four valve gates until the filling times in all cavities are practically identical (cycle 206).

An analysis of the valve gate control curve (**Fig. 4**) shows clearly that the differ-

The Authors

Dipl.-Ing. (FH) Christopherus Bader has been Managing Director of Priamus System Technologies AG in Schaffhausen, Switzerland, since 2001; info@priamus.com

Dipl.-Ing. Frank Pribbernow joined Priamus in 2008. Since 2013, he is Head of the electronics development department in Schaffhausen.

Acknowledgments

The authors express their thanks to:

- Sergio Antunes, Controls Engineering Manager, and Al Bernier, R&D Injection Molding Supervisor, both with Synventive Molding Solutions in Peabody, MA/USA;
- Wilhelm Hangweirer (automation) and Andreas Penninger (application technology) with ACH solution GmbH – Hefner moulds in Fischlham, Austria.

Service

References & Digital Version

- You can find the list of references and a PDF file of the article at ***www.kunststoffe-international.com/1383806***

German Version

- Read the German version of the article in our magazine ***Kunststoffe*** or at ***www.kunststoffe.de***

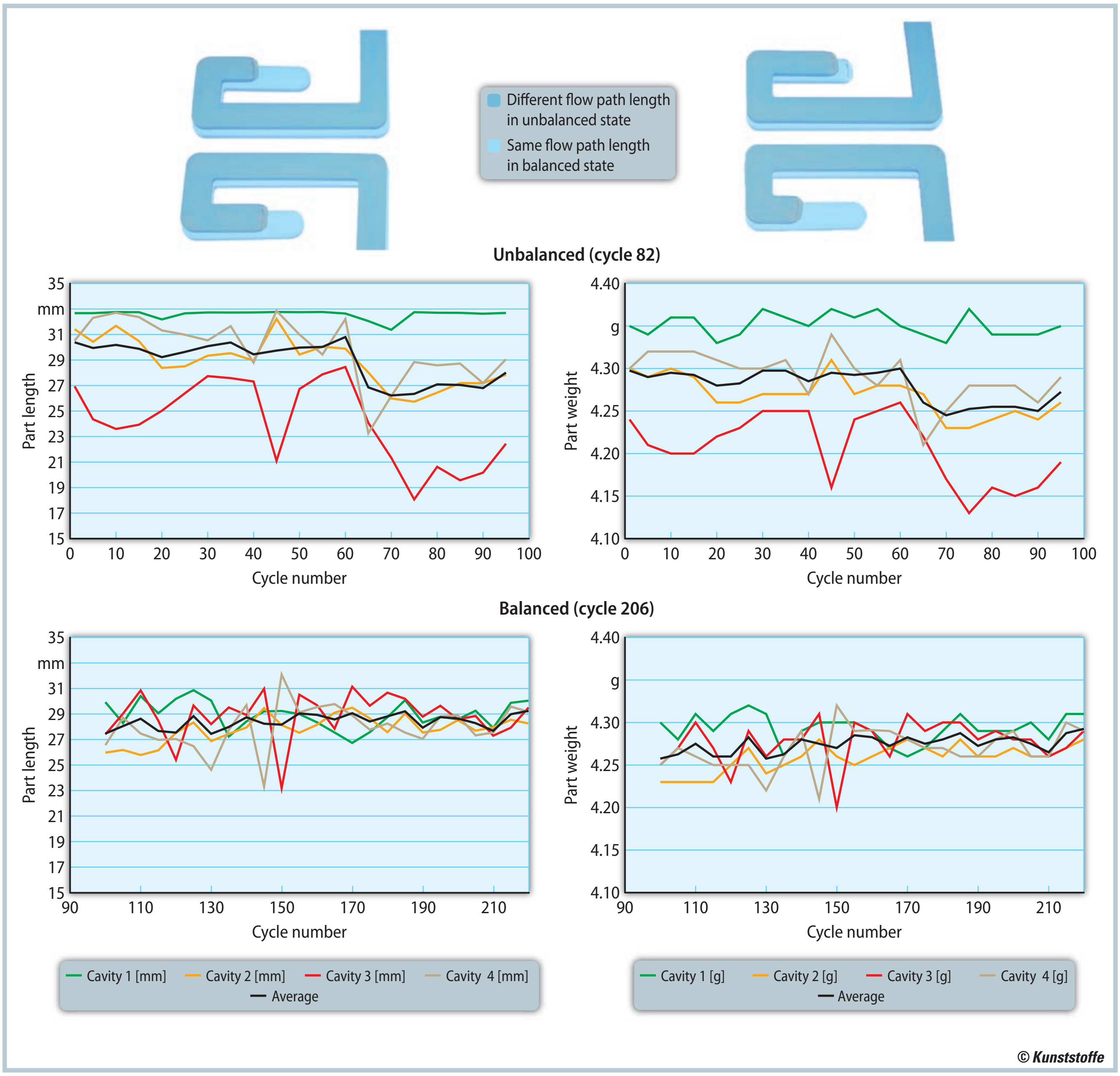


Fig. 5. An evaluation of the component weights and the flow path lengths reveals a significant improvement before and after balancing. The upper part of the diagram shows a comparison of the different spiral lengths (source: Priamus)

ent filling times are significantly reduced within just a few cycles, and are finally controlled permanently at a minimum value. Optimization of the individual filling times via manual adjustment of the valve gate stroke is inconceivable simply because a differentiation from cavity to cavity is impossible without sensors and an automatic detection of the melt front. Moreover, balancing of the different filling times is not a static process, but a process that must be controlled continuously throughout the entire production time in order to eliminate the variations due to material and ambient conditions.

A graphic diagram illustrates the direct effect of the different filling times both on shot weight and on flow path length of the individual flow spirals (**Fig. 5**). While weight and length of the moldings in the unbalanced state vary widely, they are very closely matched in the controlled or balanced state.

Liquid Silicone: Low Viscosity Causes Large Differences in Filling Time

Contrary to thermoplastic injection molding, liquid silicone rubber (LSR) molded parts are produced with a cold runner system and in a comparatively hot mold. With hot vulcanized LSR injection molding, both material components (catalyst and curing agent) are mixed, which starts the cross-linking process. During the injection procedure, the viscosity of the mixed LSR components is considerably lower than that of thermoplastic melts, which usually leads to even greater filling differences in multi-cavity molds.

Here, the melt front speeds in the individual cavities react even more sensitively, which in turn places higher demands in terms of process control. One reason is that the properties of molded silicone parts are directly dependent on the volume at which the material cures (cross-links). Consequently, if the cavities of a multi-cavity mold have different fillings, the processor must take different component qualities into account, caused by different curing behaviors, which have an influence e.g. on the size and overfilling of the components.

Because of the low material viscosity, molds for processing liquid silicone rubber are necessarily fitted with valve gates, because the volume flow of the injected material cannot be controlled in any other way. In order to test the automatic Priamus valve gate control, ACH solution GmbH – Hefner moulds, Fischlham, Austria, installed several Priamus sensors in an 8-cavity test mold for manufacturing cable ties (**Fig. 6**). Every cavity was fitted with a cavity pressure sensor (type 6010BC) close to the gate for determining viscosity, plus a cavity temperature sensor (type 4012B) just short of the flow path end. The temperature sensor was used for automatic valve gate control, as described above, whereby a pressure sensor could also have been used alternatively to detect the melt front.

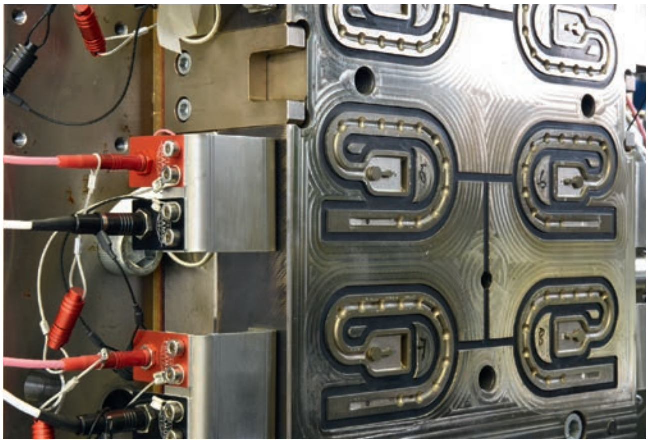


Fig. 6. An 8-cavity trial mold for cable ties was built to test the Priamus control system in a liquid silicone application (© Priamus)

Automatic Balancing of an 8-Cavity Mold for LSR

The trials with the two test materials Silpuran 6600/60 A and Silpuran 6600/60 B (manufacturer: Wacker Chemie AG, Munich, Germany) were carried out on an injection molder type Engel Victory 500 H/200L/160 Combi (manufacturer: Engel Austria GmbH, Schwertberg, Austria). ACH Hefner's Servo-Shot system was used for valve gate control, which is mounted directly on the mold and is also suitable for processing thermoplastics.

The tests provide similar results to those obtained in trials with thermoplastic material (**Fig. 7**). Hereby, due to the heated molds, the main difference is that upon contact with the liquid silicone, the cavity temperature sensors measure a temperature drop instead of a temperature increase. However, the Priamus system is able to measure temperature changes, and can therefore detect the arrival of the flow front in

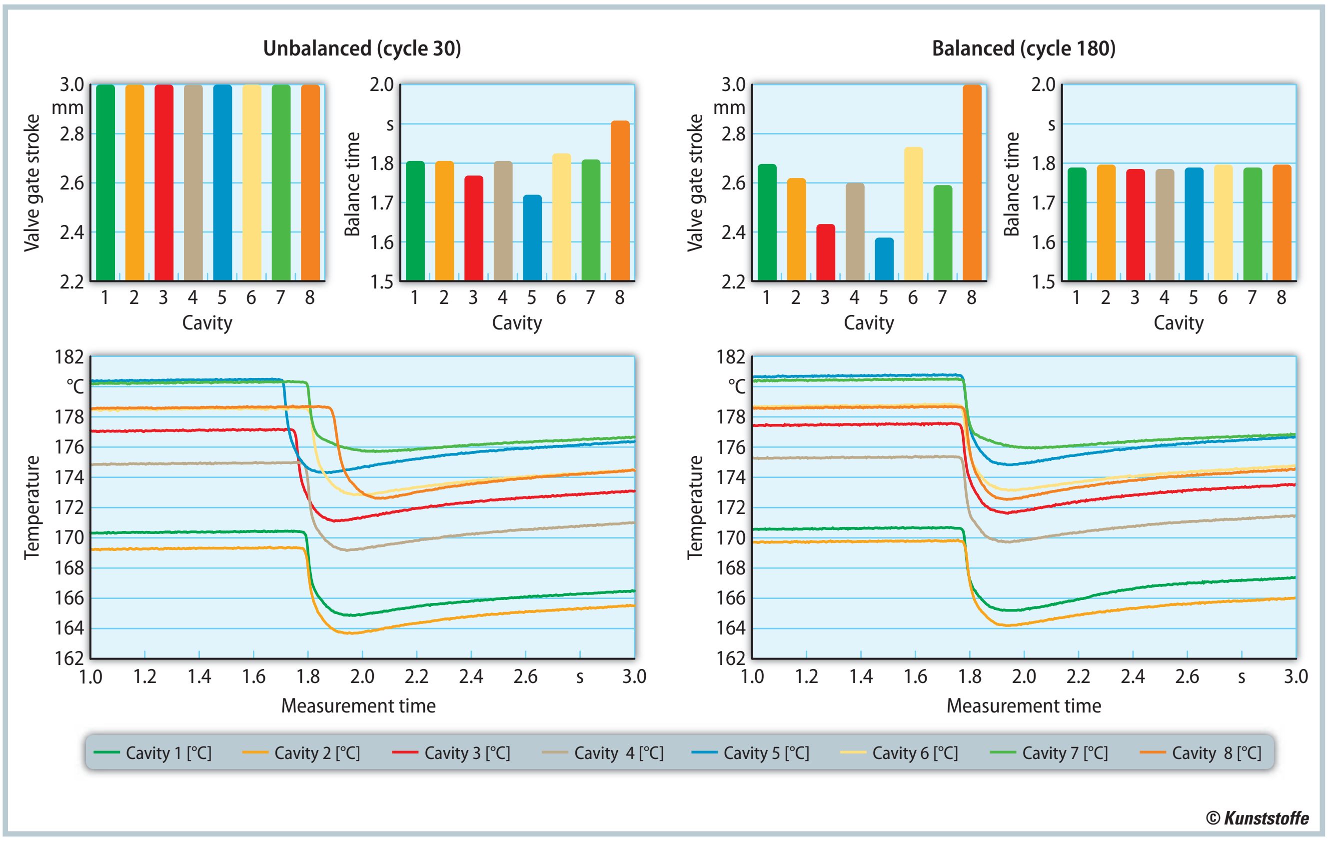


Fig. 7. The results of the trials with liquid silicone show a similar picture to those with a thermoplastic. A uniform pin stroke inevitably results in different filling times for the eight cavities (left). Only in the balanced state (right) are the cavities filled equally (source: Priamus)

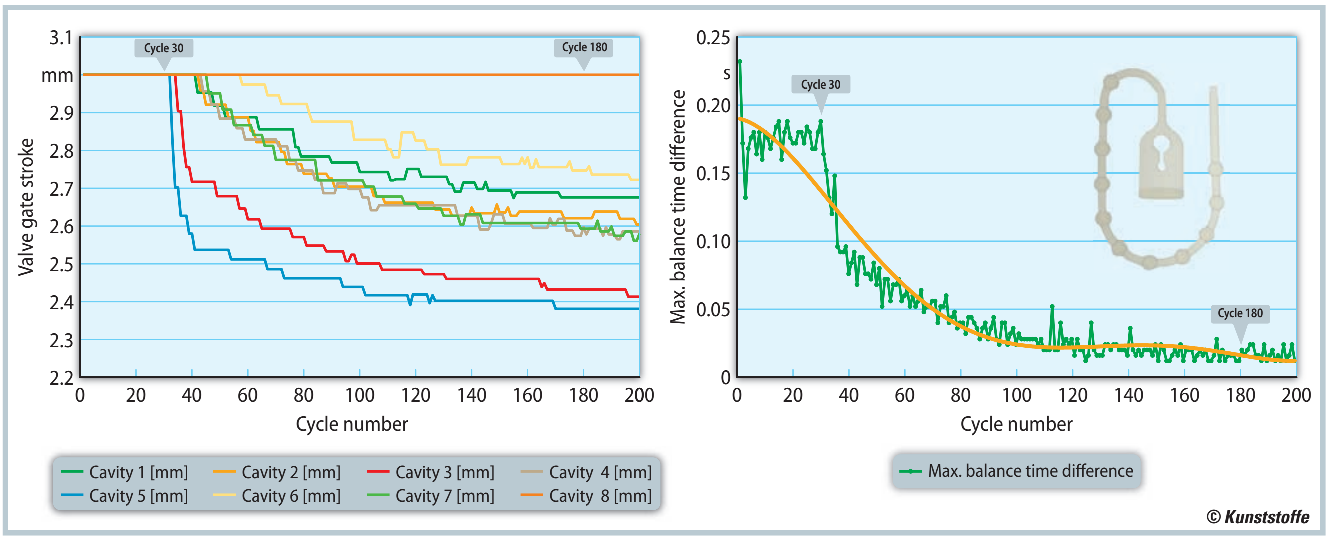


Fig. 8. Also when valve gate control is used with silicon materials, the different filling times are continuously minimized during production. Due to the curing of the LSR components, a uniform volume in the individual cavities is particularly important. Hereby, the extremely low viscosity of the material during the filling process is a challenge (source: Priamus)

both directions (rising and falling) practically in realtime. And once again, it is shown that if the same pin stroke setting is used for all the valve gates, different filling times ("balancing times") of the eight cavities will result (cycle 30) due to the unbalanced state. In contrast, with a balanced state and different pin strokes, the balancing time is practically identical in all cavities (cycle 180). Similar to the tests with thermoplastic material, the balancing time changes within a short time after activating the Priamus system, and is optimized and minimized continuously during the production period (**Fig. 8**).

Summary

Both tests showed that balancing the flow front independently of the nozzle temperatures is not only possible, but can also be used effectively. However, active balancing of the flow fronts by means of cavity sensors by controlling the pin stroke of the valve gates is only the first step towards intelligent injection molding tools. From a purely technical standpoint, quality control directly in the mold – independent of the injection molding machine – appears obvious and without an alternative for several reasons. Particularly the balancing of multi-cavity molds by the machine or the hot runner is not possible for physical reasons. Seen from this angle, the subject of process validation will have to be reassessed, and perhaps one or the other expensive machine interface could lose its right to exist. The future will show to what extent direct quality control from the mold will replace the need for complex machine controls. ■

Switzerland (Headquarters)
PRIAMUS SYSTEM TECHNOLOGIES AG
Rheinweg 4
CH-8200 Schaffhausen

Tel. +41 52 632 2626
Fax +41 52 632 2627
info@priamus.com
www.priamus.com

Germany
PRIAMUS SYSTEM TECHNOLOGIES GmbH
Postweg 13
DE-73084 Salach

Tel. +49 7162 930 60 480
Fax +49 7162 930 60 481
salesde@priamus.com
www.priamus.com

USA
Priamus System Technologies, LLC
3061 Nationwide Parkway
Brunswick, OH 44212

Tel. + 1 877 774 2687
Fax + 1 877 678 5062
salesus@priamus.com
www.priamus.com

FILLCONTROL

PRIAMUS
A business of BARNES GROUP INC

www.priamus.com

We Control Injection Molding Processes

Automatic Valve Gate Control