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Some Ways Lead to Rome, but Some Do Not

For the Purpose of Quality Assurance Right from the Injection Mold, Sensors Are Used in a Wide Range of Industries Today

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For the Purpose of Quality Assurance Right from the Injection Mold, Sensors Are Used in a Wide Range of Industries Today

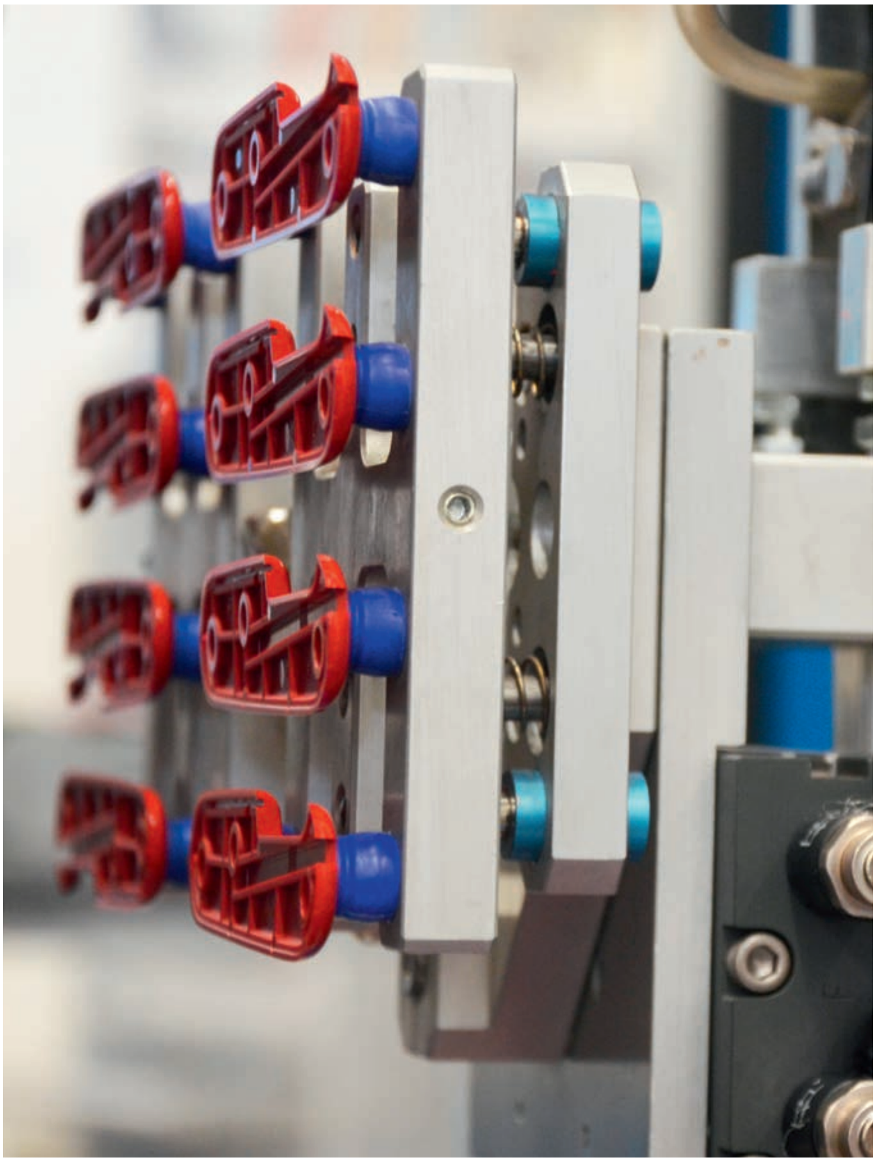
There is not a universal solution for quality assurance in injection molding. Subject to the respective application, conditions and target, several options are available to monitor the process and conduct off- and on-line control by means of cavity pressure or cavity temperature sensors. Solutions from medical technology, the automotive and consumer goods industry serve as examples to show the wide range of practical applications.

It might be sensible in some cases of injection molding with mold sensors, to merely monitor the packing or the complete filling of a molding in order to sort out reject parts automatically. In many cases, however, it may be a good idea to use the mold information at hand for direct control and on-line control purposes, in order to optimize and reproduce the process in an optimum way. This is because this is neither possible by simulation nor within the machine, due to the fact that the actual conditions in the mold are unknown and even change continuously.

First Comes the Problem, then the Solution

Before a process is monitored, controlled on-line or changed basically, analysis is required to define the exact target. To make this process clear, this article will describe some examples of solutions from medical technology, automotive and consumer goods industry.

The story of success of Victorinox AG in Ibach, Switzerland, began long before people started thinking about injection molding. The Swiss Army Knife, which is the most widely known product of the company, has always been one of those products that meet the highest demands in terms of functionality, reliability and quality (**Fig. 1**). This is not only restricted to the knife's technical properties. It also means the optical appearance of the



Shells of the Swiss Army Knife produced by injection molding (figures: Priamus)

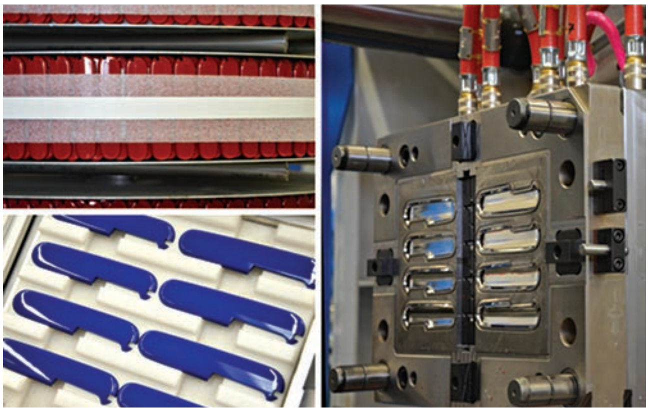


Fig. 1. Producer Victorinox poses the highest requirements to the surface of the shells. The process window must be narrow and controlled to enable homogeneous qualities

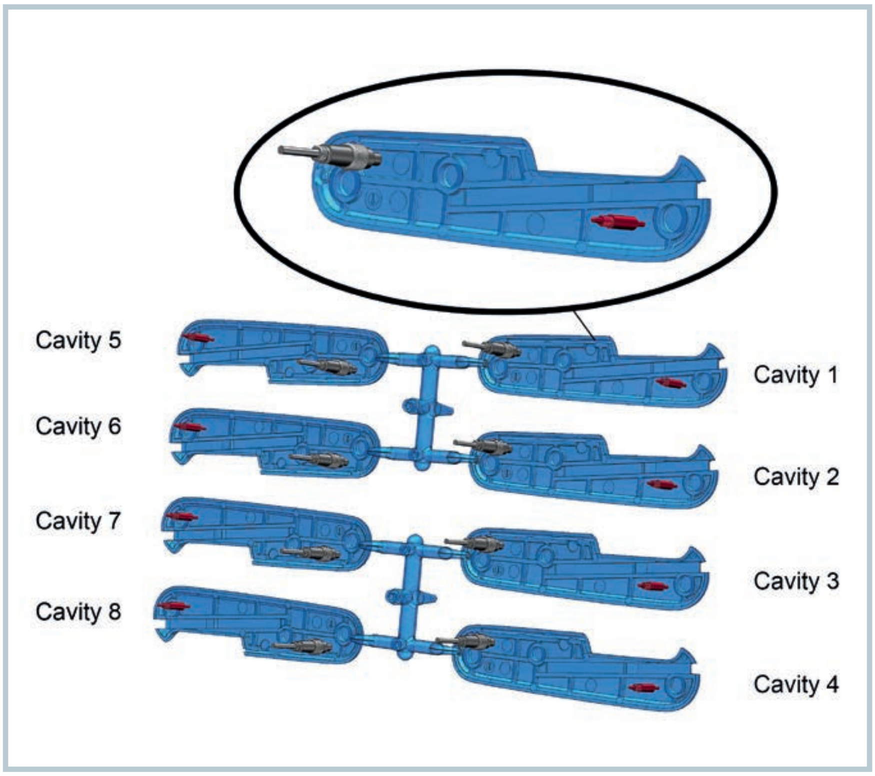


Fig. 2. Because the sensors in the 8-cavity mold sit in a symetrical position, not only maximum pressures and mold temperatures can be compared directly. It is even possible to compare flow properties (viscosities) in the individual cavities

knife grip shells, which is why the company decided to get to the bottom of the process.

For this purpose, an 8-cavity hot runner mold with sub-manifolds was equipped with a cavity sensor (type: 6007BC) and a mold wall temperature sensor (type: 4004A, **Fig. 2**) in each cavity. The manufacturer of both sensors is Priamus System Technologies AG, Schaffhausen, Switzerland. The symmetric positioning of the sensors not only makes it possible to measure pressures and temperatures inside each cavity, but even to analyze the melt front and the respective viscosities.

The greatest difficulty during production is actually the fact that, not even today, the high surface quality required can be checked fully automatically at final check. At the same time, it is necessary to reproduce reliably the set distance between the rosettes at the shell's rear side. So the aim is to control and reproduce the process within a narrow window, preventing any signs of overspraying or slight waves in the surface. At the same time, the required dimensions must be adhered to. The actual design (sub-manifolds) as well as the share of recyclates of up to 30 % interfering with process stability are the challenges to be handled here.

The Author

Dipl.-Ing. (FH) Christopherus Bader has been leading manager at Priamus System Technologies AG, Schaffhausen, Switzerland, since 2001.

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Effects on Melt Flow and the Shrinkage of Moldings

The chart (**Fig. 3**) shows the distribution of the individual cavity pressures and cavity temperatures in the eight cavities, as well as the effect of these parameters on the shrinkage of each molding. Temperatures were controlled dependent on pressure values, adjusting tempering of the mold accordingly. Generally speaking, several effects revealed:

- While temperatures at the surface vary within a narrow range, the changes in shrinkage values (= temperatures at a certain pressure) are much more pronounced.
- The order of the measured absolute temperatures (T2, T7, T3…T4) is different from the order of shrinkage values (S1, S4, S5…S6). The shrinkage of the moldings is thus not equal to the absolute temperatures measured on the surface.

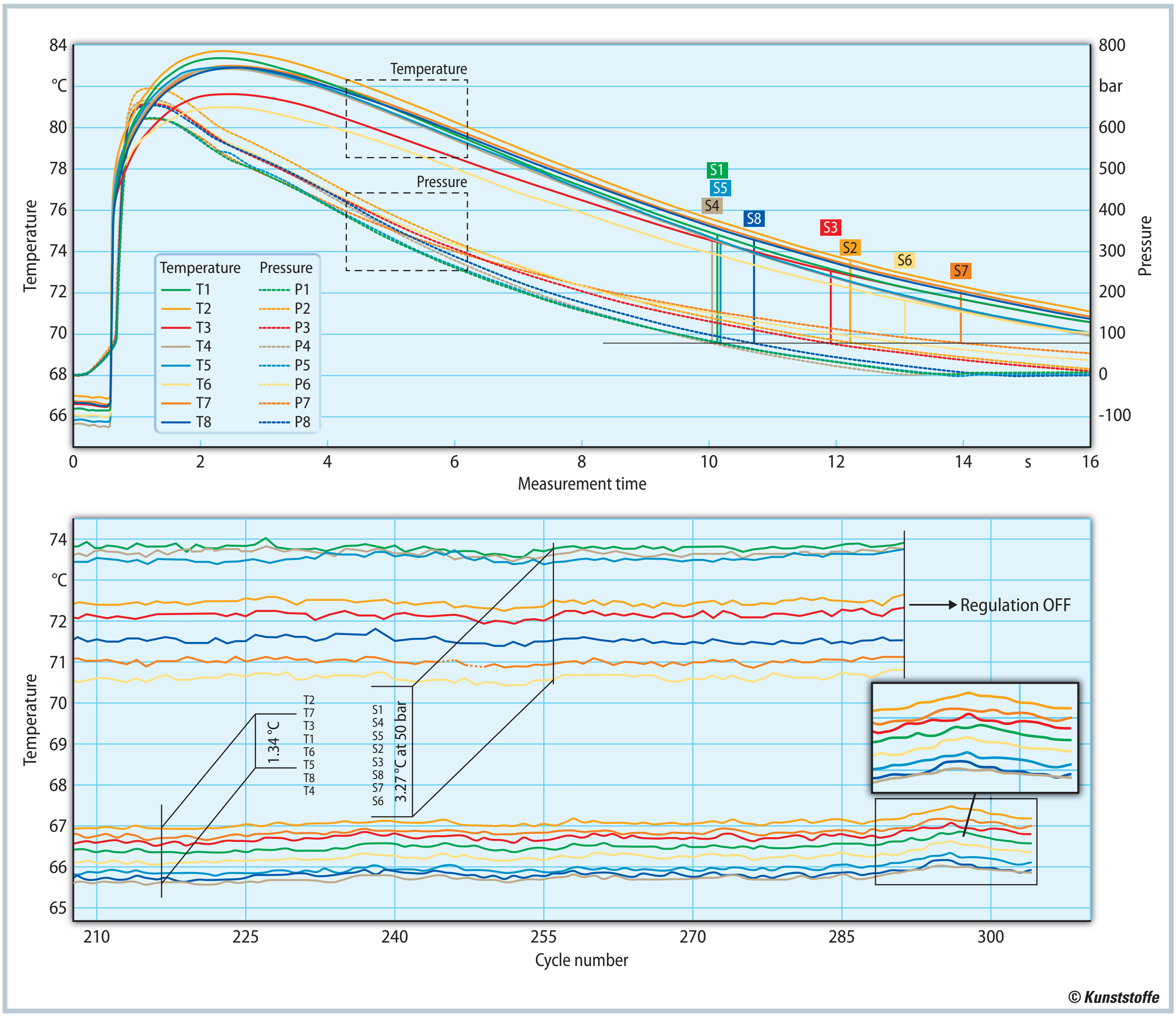

Fig. 3. Cavity pressures and mold temperatures of the eight knife shells (top) as well as trend graph of mold temperatures, including shrinkage values (= temperatures at a certain value) resulting. The order of the measured absolute temperatures (T2, T7, T3…T4) is different from the order of shrinkage values (S1, S4, S5…S6). After switching off the on-line control unit, surface temperatures rise significantly. This shows that without on-line control dimensional stability can be expected to deteriorate

- After switching off the on-line control unit, surface temperatures rise significantly. This shows that without on-line control dimensional stability can be expected to deteriorate.

Even though cold runner sub-manifolds are used here, filling behavior in the individual cavities is extraordinarily well balanced. This can be deducted from the fact that the temperature signals at the end of the flow path increased virtually at the same time (**Fig. 3**). Neither do the pressure signals at the beginning of the flow path show any time difference (**Fig. 4**); this finding, however, can hardly serve to evaluate a homogenous balance in cavity filling, with the melt still having to flow through the entire cavity. The chart also shows that the time difference in pressure rise is unsuited to serve for the evaluation of the balance, because it constantly changes or increases.

The pressure curves (**Fig. 4**), however, show the behaviors of the individual cavities during filling and packing. Due to the mold, pressures within the cavities differ, while the maximum values inside the cavities are reached roughly at the same time. It is interesting to note that pressures decrease differently, so that the value of 80 % of maximum pressure is reached at different points in time inside the individual cavities. This is why Priamus, in order provide for on-line control of packing pressure (type: 7080A Fillcontrol Control M), does not use maximum pressure, but so-called compression pressure in the cavities, which obviously results from compressing the molding, not with filling [1].

On-line Control of Filling Time and Hot Runner Balancing

The medical division of Weidmann Plastics Technology AG, which is part of Wicor Group, manufactures medical products under cleanroom conditions, in accordance with ISO 7 and ISO 8. The production sites are in Bad Ragaz in Switzerland and Auburn in Alabama, USA. An exam-

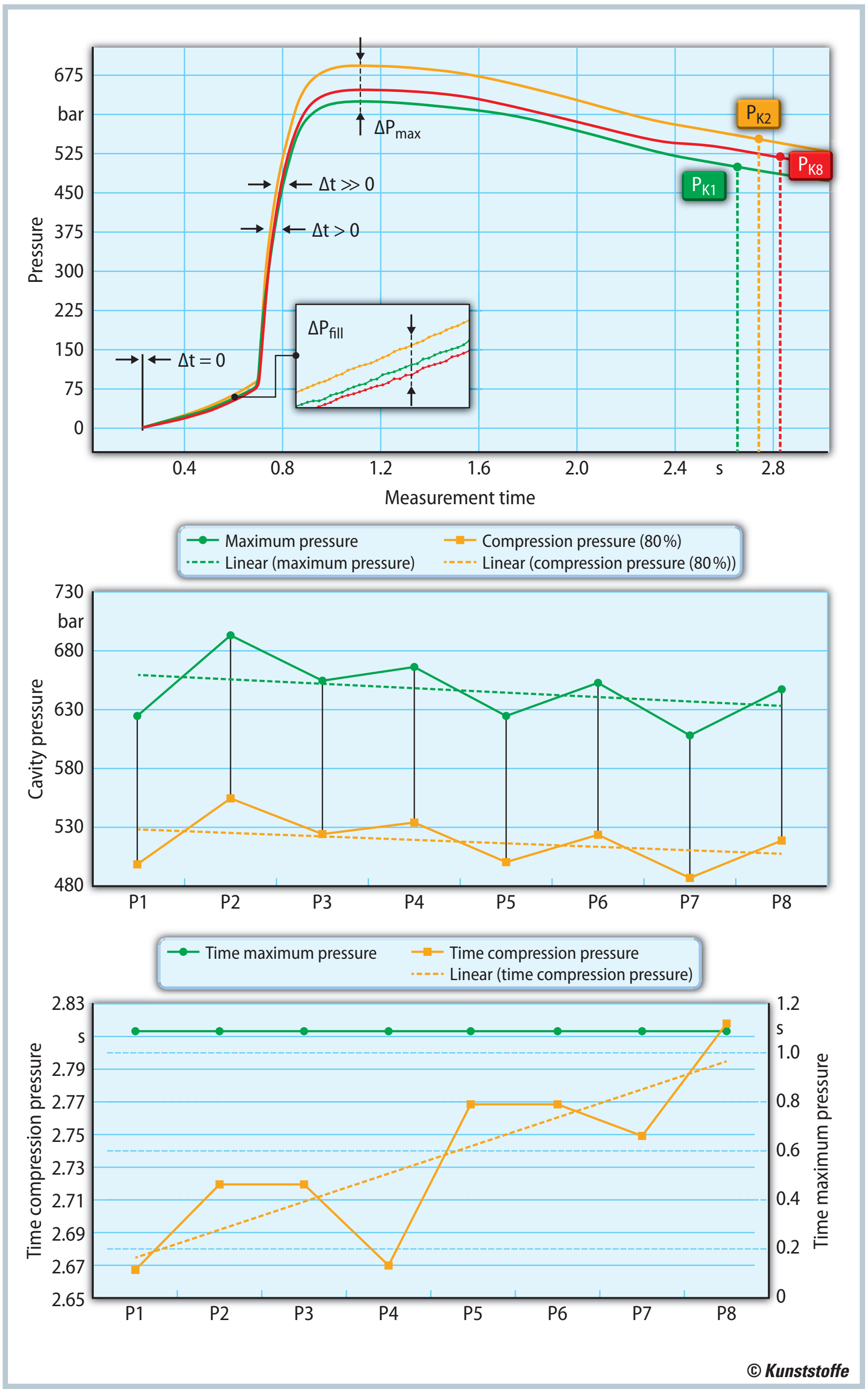

Fig. 4. Pressures decrease differently in every cavity, while the respective maximum values in the cavities are achieved at the same time (to make the presentation clearer, it shows only three of eight curves). To make sure the compression process is controlled dependent on packing pressure only, the compression pressure at 80 % of maximum pressure, instead of maximum pressure, serves as the parameter of on-line control. The two charts at the bottom show the distribution of the individual maximum and compression pressures over the eight cavities, as well as the time difference between the pressures in the cavities

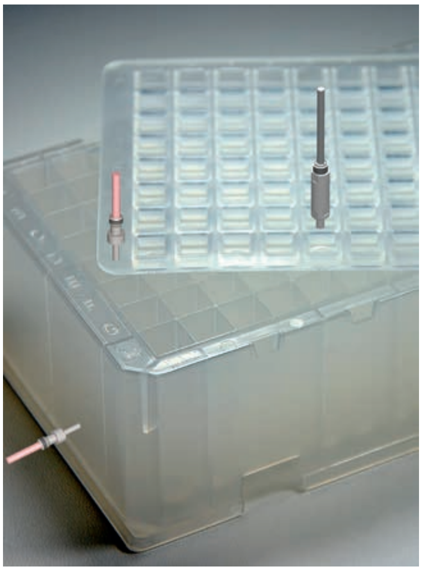

Fig. 5. Initially, the lower part is balanced automatically via the hot runner nozzles in a two-component mold, while the filling times of both components are controlled inside the cavity using the wall temperature sensors

ple of this production is a combination of cover ("sealing mat") and basic part („well plate") designed to store blood samples. This product is used in highly automated laboratories to store and protect the empty or filled storage plates from soiling, dust and other particles (**Fig. 5**). The two moldings must therefore close easily in all openings, and require little power for drawing off the sealing mat.

The sealing mat is produced from an EVA material in a single-cavity mold (type: Elvax; manufacturer: DuPont), while the well plate is made of PP (type: Purell; manufacturer: Lyondell Basell) in a two-cavity mold. In both cases, a critical aspect is to safeguard homogenous filling of the moldings as well as constant filling times. In the second case of the well plate, though, the two cavities are balanced automatically by hot runner nozzles [2] before. In both applications, a reference filling time measured in the cavity is finally stored and reproduced via the automatic Priamus hot runner control unit. Both processes are monitored by means of the cavity temperature and the maximum pressure inside the cavity.

Real Time Control and Process On-line Control Complement one Another

Looking at an application of Lameplast S.p.A in Rovereto, Italy, it becomes obvious that real time control, subject to its position is the melt during filling, and hot runner balancing are not mutually exclusive. In fact, the opposite is true – they perfectly complement each other. The enterprise is a specialist in the production of primary packagings, specially for the pharmaceutical industry, for instance single dose containers (**Fig. 6**). The challenge posed by this application is that simultaneous filling of the five cavities must be synchronous with pulling of the five cores. »

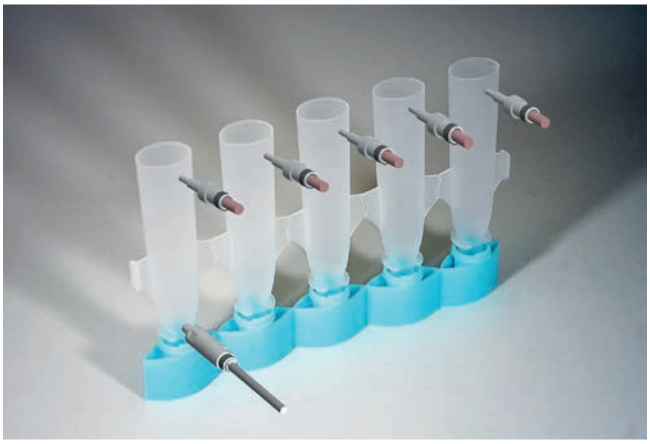

Fig. 6. Single-dose containers for eye-drops. Using the mold temperature sensors, the hot runner nozzles are balanced and the cores pulled back from the cavities at the same time

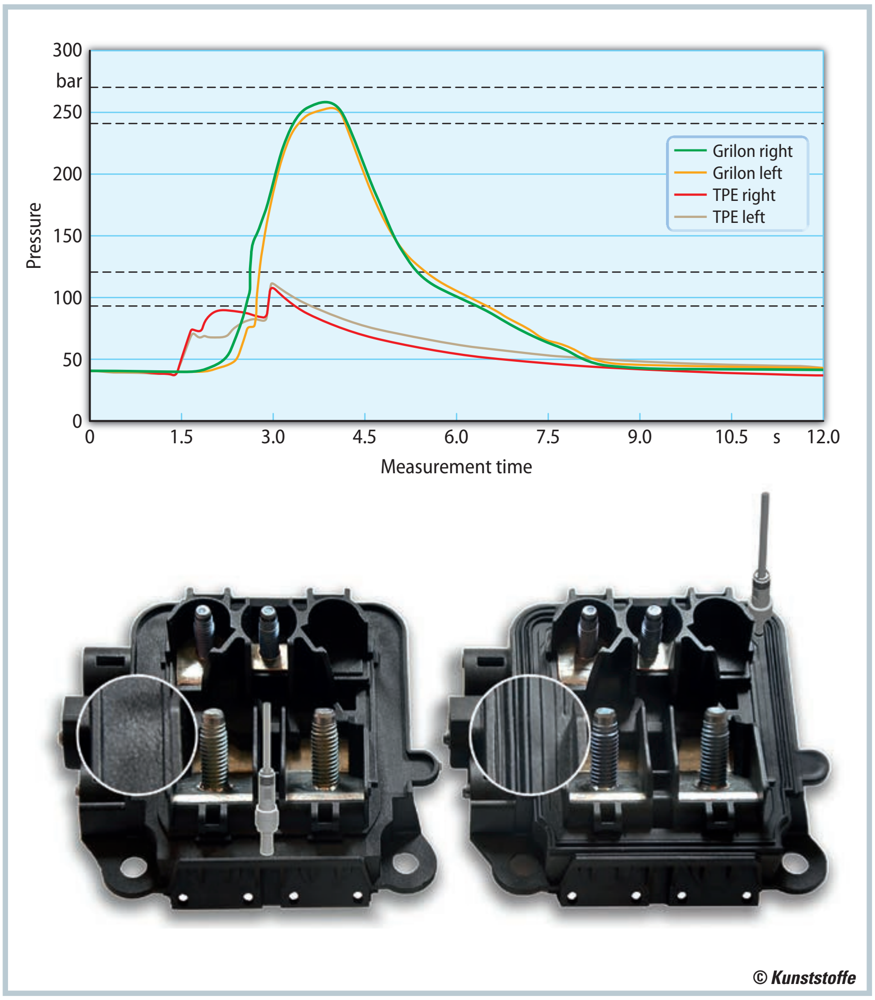

Fig. 7. Process monitoring for a two-component bus bar via cavity pressure sensors. Because this is a rotary table application, both components must be monitored separately, and sorted out in case of a bad part (bottom left: without soft component; bottom right: including soft component)

This is why mold temperature sensors (type: 4004A) are placed prior to the end of each flow path. The sensors automatically detect the melt front in the individual cavities – which is the prerequisite for balancing the hot runner (type: 7080A Fillcontrol Control H). At the same time, the signals are also used to pull the cores automatically at the right moment so as to achieve the consistency required for the next processing stage (type: 7080A Fillcontrol Switch). In addition, a cavity pressure sensor (type: 6008A; manufacturer of both: Priamus) is placed near the gating, to determine and monitor the viscosity between pressure and temperature sensor.

Process Monitoring Combined to Rotary Table Applications

Simply monitoring the process can well mean a challenge to the engineer, in particular if the task is to monitor a multi-component application with a rotary table, which is the case when producing bus bars (**Fig. 7**). Manufacturer Intercable Srl. in Bruneck, Italy, is one of the major plastics producers in Northern Italy today, supplying all renown automotive manufacturers all over the world via various distribution channels. In addition, Intercable produces and manufactures products for the energy distribution sector. The named components are injection molded in a two-component mold on a master-slave machine, and both components are processed via two aggregates at the same time, i.e. in a synchronized mode. Shot weights are 402 g (Grilon TSG-30; supplier: Ems-Chemie) and 9.5 g (TPV), respectively.

In each cavity, and for each component, a cavity pressure sensor is integrated (rigid component: type 6002B; soft component: type 6003B, manufacturer: Priamus) to monitor maximum pressures. Even though in this example both components are monitored at the same time, it is possible with the Priamus system (type: 7080A Fillcontrol Switch) to sort out each single component. If a rigid component is detected as a bad part, the on-line process control prevents injection molding of the soft component.

Conclusion

The examples described here give an insight into which possibilities are available of quality assurance right from the mold for a wide range of industrial applications. As can be seen, merely measuring cavity pressure or mold temperature fails to generate the desired process safety and cost saving results. It is necessary to employ a suitable system to process the signals in a sensible way. In the past, a frequent task used to be to develop stand-alone-solutions for certain applications. In the future, there will certainly be processes that enable quality assurance entirely independent of machine and material, by using mold sensors. ■