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Dynamic Temperature Measurement as a Prophylactic Against Rejects

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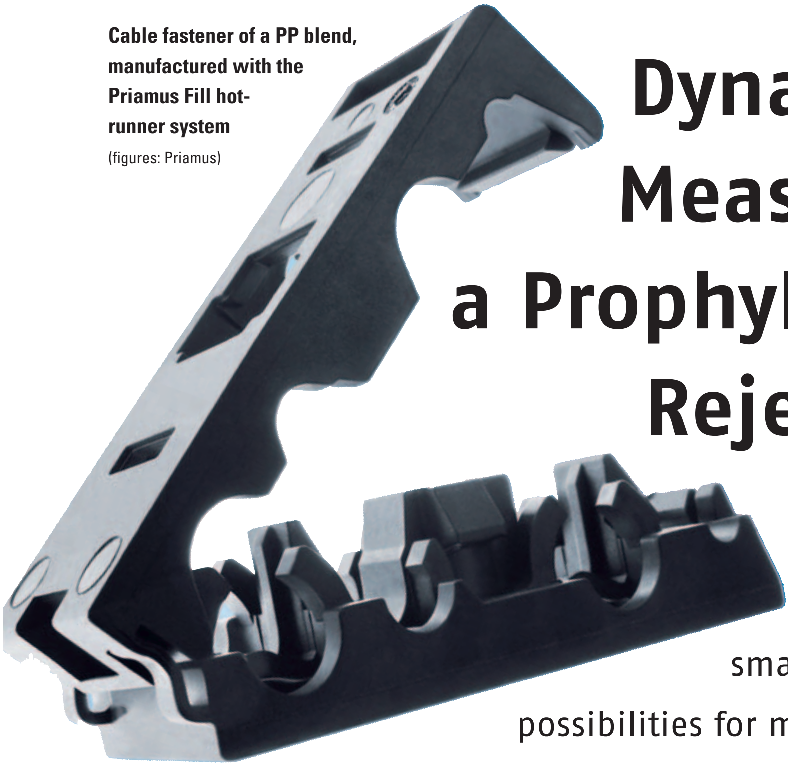

Cable fastener of a PP blend, manufactured with the Priamus Fill hot-runner system
(figures: Priamus)

Dynamic Temperature Measurement as a Prophylactic Against Rejects

Hot-Runner Balancing. The capabilities of modern sensors, together with smart system technology, open up new possibilities for meeting the requirements made on the injection moulding process. Cavity-temperature-based closed-loop control systems respond in real time to natural fluctuations in the process. As they improve part quality in this way and demonstrably reduce reject quotas, the use of such systems also pays off economically.

ERWIN KÖNIG

The increasing complexity of injection moulds, together with the process reliability that is now taken for granted, makes it more important than ever to match the individual manufacturing steps to one another. The system control system must therefore be capable of responding to changes in the process. Process engineers often generally assume that fixed process-parameter settings ensure a constant high part quality, presupposing that the injection moulding machine is characterised by accurate reproducibility. However, because of continual fluctuations in melt viscosity and other effects, such as batch-to-batch fluctuations, this assertion is not generally supportable. Very often, an optimised process is only sporadically and manually adapted to such changes, if at all. From an objective point of view, automatic and permanent adaptation of the machine parameters and switching signals to the process fluctuations would be desirable to ensure high part quality in the long term.

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Sensors Located Where the Part is Moulded

The key to this is formed by cavity pressure and cavity temperature sensors in the cavity, which register every change in the injection moulding process – at the points where the part is moulded. Deviations must be responded to with intelligent switching and control systems. In this

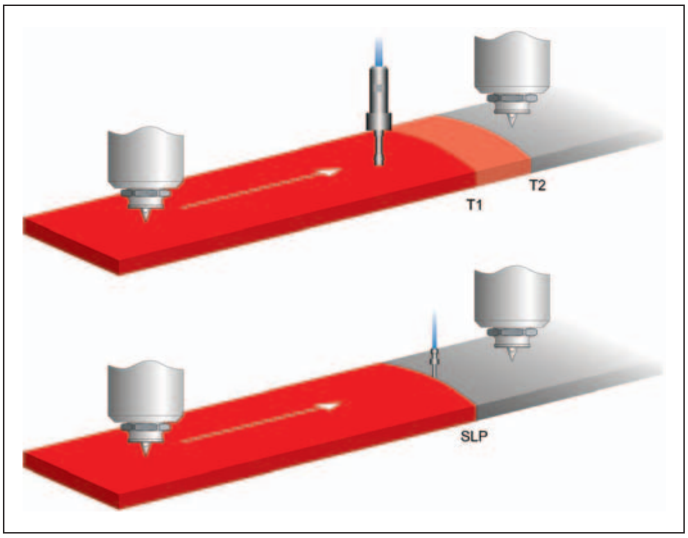

Fig. 1. Top: sequential opening of a nozzle by a cavity pressure-dependent switching threshold. Since the melt front continues to move until it reaches the threshold, and reaches a different position depending on its viscosity, this process is not suitable for controlling cascade injection moulding processes.
Bottom: sequential opening of a nozzle depending on the melt front. A cavity temperature sensor recognises when the melt has reached it independent of viscosity fluctuations

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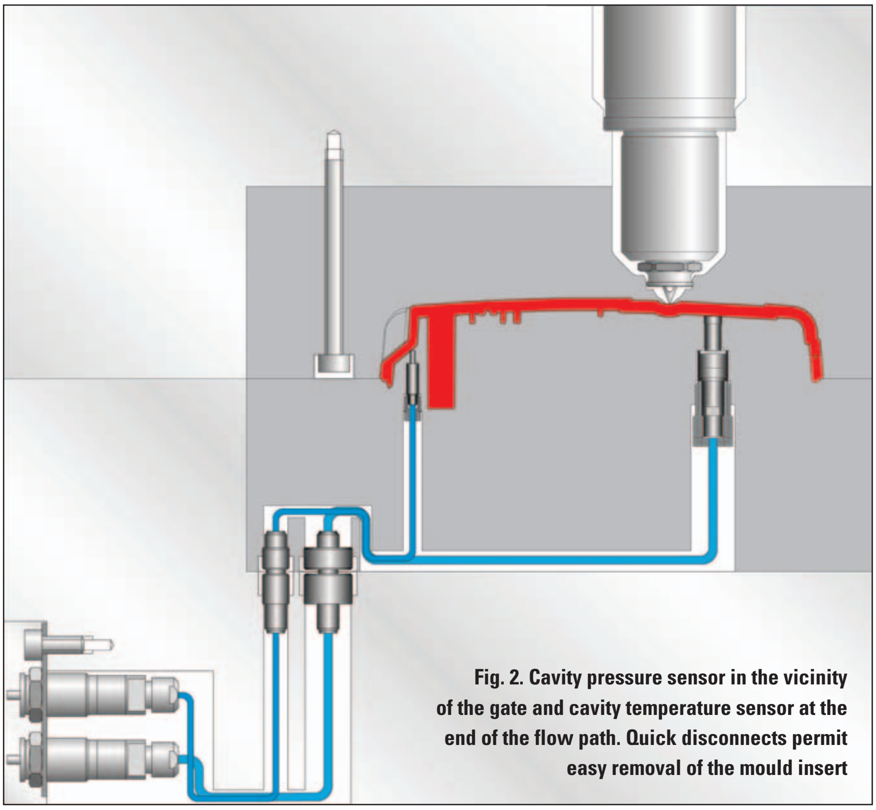

Fig. 2. Cavity pressure sensor in the vicinity of the gate and cavity temperature sensor at the end of the flow path. Quick disconnects permit easy removal of the mould insert

way, the control can automatically change over to holding pressure within a few milliseconds depending on the flow front, which is reliably detected by means of temperature sensors at the end of the flow path [1]. The advantage of this principle, which has been patented by Priamus, compared to cavity pressure-dependent or position-dependent changeover to holding pressure is that this adaptive process continually matches the changeover point to the fluctuating viscosity, and thus automatically avoids overfeeding of the parts or filling under holding pressure.

Another way of making the process safer is flow front-dependent active venting. In this process, an active venting element, which is opened during the injection phase, is automatically sealed when a temperature rise is measured as the melt reaches the sensor [2]. The same principle is also used for core pullers or other movement elements. As soon as the melt reaches the temperature sensor, switching signals are automatically generated to release holding or gripping functions for holding, e. g., insert parts.

During cascade injection moulding, too, the individual nozzles are opened consecutively depending on the flow front, that is to say automatically and at the correct time (Fig. 1). Position-dependent processes only produce inaccurate results as a result of volume fluctuations of the moulding compound and flow differences. Cavity pressure-dependent processes for sequential opening of the nozzles by means of pressure thresholds are not suitable in principle, because the relative pressure at the sensor front is only 1 bar (atmospheric pressure), and only rises as the cavity is progressively filled.

Avoiding Non-uniform Cavity Filling

Measurement of the cavity temperature, either directly in all cavities of a multi-cavity mould or in the region of each cooling circuit of a large-area part, provides information about the state of an injection moulded part. Here, the temperature has a crucial influence on the shrinkage, and therefore on the dimensions of the parts. In practice, when users set the mould temperature, they often make use of the display on the temperature control unit, which measures the temperature in the supply and/or return flow, though it remains unclear what temperatures are actually prevailing in the individual cavities, and whether they are all the same.

Even an individual temperature sensor installed „somewhere“ in the mould – outside the cavity – does not help much. The same applies to radiation pyrometers or thermographic cameras, which only show a snapshot of the actual temperature flow at the surface of the cavity, but not the differences and changes during production. The Priamus Cool control system, by contrast, analyses the individual signals of the cavity temperatures and thus permits automatic temperature control of individual control circuits until the surface temperatures in each cavity are at the same level.

The above-mentioned examples speak in favour of the more intensified use of such sensors in the mould. To make it easier to handle these sensors more easily in an industrial environment, Priamus System Technologies AG, Schaffhausen/Switzerland, recently developed solutions that are already finding use in practice. The Priased sensor and sensitivity detection for cavity-pressure sensors makes sensor-specific setting unnecessary and prevents incorrect data entries and assignment errors. The Priasafe principle prevents faulty measurements by first incorporating the actual cavity pressure sensor into a protective sleeve, then calibrating and storing the sensitivity value in the sensor. A quick disconnect system [3] for pressure and temperature sensors ensures rapid connection between the mould insert and mould platen, ultimately permitting problem-free installation and maintenance of the mould (Fig. 2). The sensors can therefore be used with interchangeable inserts.

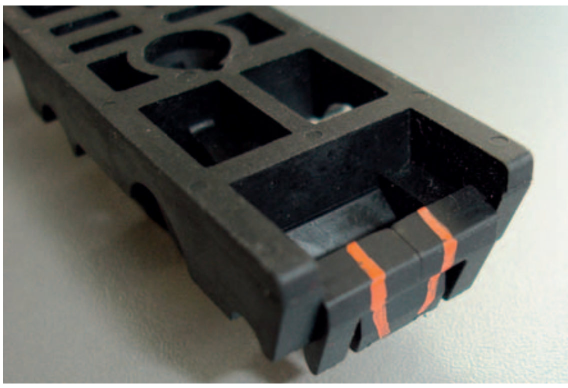

Fig. 3. Weld at the flow-path end of a cable fastener

Parts that are not uniformly filled are commonly the result of errors in the use of multicavity hot-runner moulds in all areas of injection moulding. The aforementioned viscosity fluctuations can be caused by fluctuating material quality, alternating ambient conditions and amplifying or mutually

Fig. 4. The cavity temperature sensors integrated into the 8-cavity hot-runner mould automatically balance the hot runner

compensating, unsynchronised cooling circuits. They do not occur through the entire production time, but also between the individual cavities within a shot – with the consequence of non-uniform cavity filling. That also means that the set point for changeover to holding pressure in this case is always only optimum for one or a few parts, but never for all the parts of a shot.

Hot-Runner Control System for Balancing the Cavities

A. Raymond GmbH & Co. KG, based in Lörrach/Germany, which claims to be a market leader in special fastening systems for the automotive industry, employs 1,350 employees in Germany alone and makes annual sales of about 200 million EUR. The factory in Weil am Rhein, Germany, makes use of cavity temperature and cavity pressure sensors to automatically control and monitor the injection moulding process.

In the following case, despite manual control before installation of the sensors, reject parts continually went unrecognised, a problem that caused Raymond considerable overheads for post-sorting. For example, in a cable fastener (Fig. 3) at the end of the flow path, welds occurred, which affected the strength of the part. Likewise, incompletely filled parts were manufactured, which did not fulfil the required snap-fastening function. This behaviour was partly attributed to the fact that the PP blend used, which is tailored to the requirements of the automotive industry, is difficult to process. For example, the strength–and function of the part must be guaranteed within a temperature range from –40 to +120 °C. Those responsible at Raymond therefore decided to use the Priamus Fill hot-runner control system for producing this part – primarily not only because it identifies and excludes the reject parts but also to a large extent precludes the production of faulty parts.

A dynamic cavity temperature sensor was therefore installed in each of the eight cavities of the hot-runner mould (Fig. 4). The necessary positioning of the sensors directly at the problematic area was difficult because of the geometrical arrangement of the cooling channels, but was eventually satisfactorily solved. From the temperature profile in the individual cavities, a reliable distinction can now be made between completely and incompletely filled parts. Whereas it is absolutely necessary for automatic balancing and monitoring of mould filling to have a cavity temperature sensor in each cavity, for better assessment and monitoring of the entire, it is sufficient to employ a cavity pressure sensor in only one cavity, since, with balanced filling, the pressure profiles in each cavity are almost identical. Differences in the pressure level and pressure rise no longer occur. Instead, the entire cavity pressure-level is reduced, since there are no longer pressure peaks from the cavities filled first, as occurs in unbalanced moulds. In turn, that is less stressful for the mould. The cavity pressure sensor was placed in a cavity close to the sprue to make the process as transparent as possible from the start of the injection phase.

A multichannel amplifier to which the pressure and temperature sensors can be connected is linked to the injection moulding machine via a standardised PDDI interface (Priamus Digital Data Interface), so that the control system can transmit the control signals and the classification as acceptable or unacceptable parts. The multichannel amplifier is connected to the control system – in this case a separate hot-runner control unit from Gammaflux Europe GmbH, Wiesbaden/Germany – via an RS 485 interface with Euromap 17 protocol.

To minimise the production of incompletely filled parts, the eight cavities are automatically balanced via the control system (Fig. 5). The temperature rise at the end of the flow path indicates which cavities have been filled too early, and which too late. The melt viscosities in these cavities are then matched by automatically increasing or lowering the temperatures of the respective hot-runner

User

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Temperature Curves of the Balanced Mould

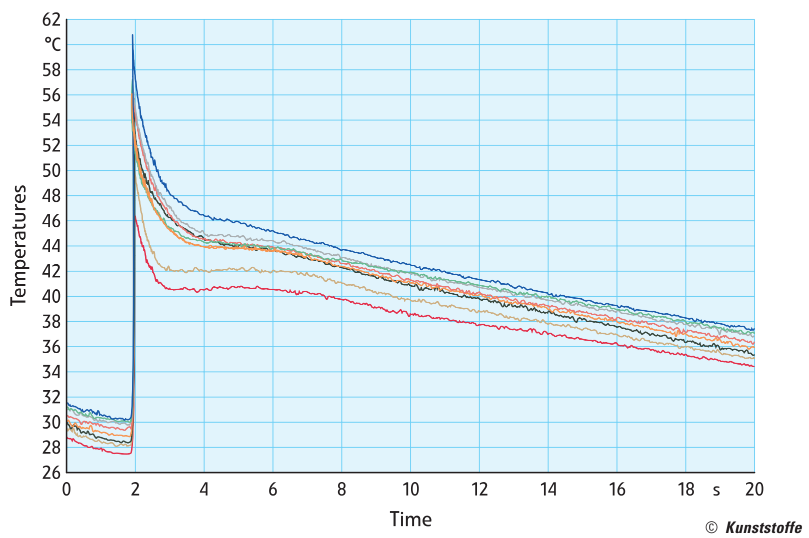

Fig. 5. Automatic balancing of the eight cavities via the closed-loop control system prevents incompletely filled parts being produced

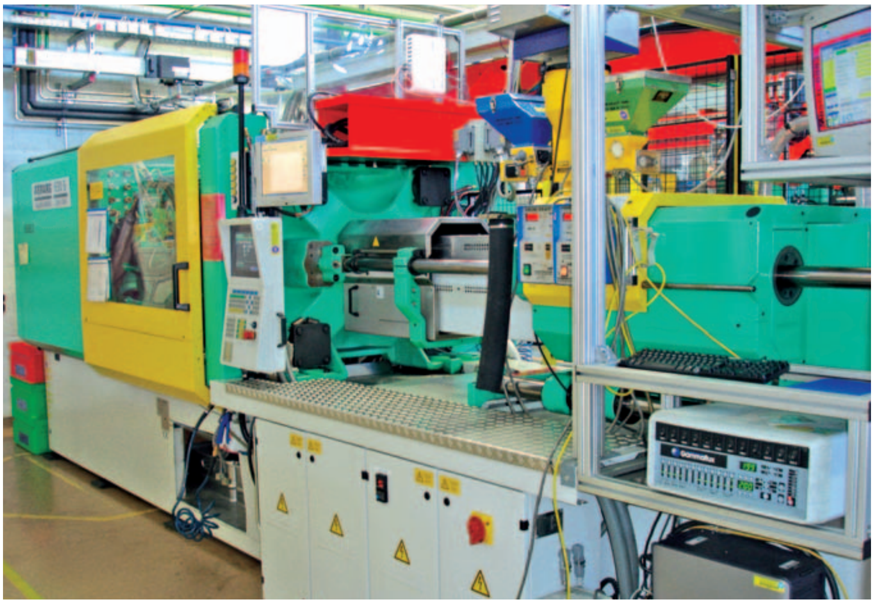

Fig. 6. The manufacturing cell for an underbody spoiler operates with the Priamus Fill hot-runner control

nozzles. This prevents process drift and thereby reduces the reject quota and process costs correspondingly.

Positive Experiences from an Automotive Supplier

Shortly before the automatic hot-runner balancing was brought into operation at the Weil am Rhein factory, 5.2 % unacceptable parts had to be manually sorted out. However, it is fair to assume that the lack of process monitoring means that the actual reject quota was higher. The filling time difference between the cavity filled first and that filled last was up to 0.5 s. After system integration, it was first noticed that the process runs more stably and the quality of the part surface is improved.

Objective proof is provided by the statistics: with 1.5 million parts produced per year, only 0.8 % unacceptable parts were automatically sorted out. The filling time different was on average only 0.05 s, and was improved by a factor of 10 by the Priamus Fill automatic control. Since manual control is no longer necessary, the factory saves about 20,000 EUR labour costs per year. This does not take into account processing of complaints, material costs, machine and setting times. Since the system was brought on stream, Raymond has not received any more customer complaints.

After the acid test had been passed according to both process engineering and economic criteria, the production management decided to employ two further systems in a manufacturing cell for underbody spoilers. The manufacturing cell, which comprises two injection moulding machines, linear robots and an optical testing station (Fig. 6), revealed similar defects on the moulding, which were not recognised by image processing, but were identified by the Priamus Fill control system.

Summary

Cavity pressure and cavity temperature sensors increasingly form a basis for deliberately reducing reject rates and costs in injection moulding production. The latest developments such as the above-described sensitivity recognition or new quick disconnect concepts greatly aid the handling of the sensors.

Intelligent systems for control of the injection moulding process permit significant improvements in quality and constancy of the manufactured injection moulded parts and at the same time high reliability in rejecting unacceptable parts. Cavity temperature sensors are increasingly used for recognising the melt front for open-loop or adaptive closed-loop control of processes in real time. ■

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