Working with instead of against One Another

Integrated Temperature Control Solution for Reduced Rejects and Greater Energy Efficiency

In the last decade, injection molders have increasingly come to focus on mold temperature control. Temperature-control units with a speed-regulated pump form an ideal complement to closed-loop controlled water manifolds. Since they are integrated into the machine control system, synergies arise that allow easy determination of the flow rates that are actually required, automatic setting of the pump speed, and consequently a significant reduction in the energy consumption.

Whereas on modern injection molding lines, traverse movements are precisely controlled to within a few micrometers; processors struggle with hundredths of a second in the cycle times; and energy consumption is minimized with highly efficient drive systems, there is another influencing factor that is paid far too little attention. This concerns mold temperature control. As for the last 30 years, the flow rate is still regulated by means of variable area flow meters, which do not allow genuine monitoring of the temperatures and flow rates. A poorly temperature-controlled mold can quickly become a cause of rejects.

In recent years, however, a trend has developed towards monitoring and controlling the cooling parameters by means of electronic water manifolds. Manually adjustable designs already offer the significant advantage that they enable process monitoring. Documentation of key process parameters is required particularly in medical technology and the automotive industry. Automatically controlled designs are also capable of maintaining constant flow rates, even if, for example, there are fluctuations in the supply pressure. In addition, the chosen settings are stored together with the part data.

With the new e-temp temperature control units developed by HB Therm, Engel has become a system supplier in the field of temperature control and can thereby offer new functions (© Engel)

What Flow Rates Are Necessary?

In determining the correct flow rates, two goals are pursued:

- Turbulent flow [1]: This ensures good heat transfer between the mold and heat-exchange medium. The flow turbulence is described by the Reynolds number. It is calculated using the cooling channel diameter, the flow rate and the density and viscosity of water.
- Uniform temperature distribution: By absorbing or emitting heat, the heat-exchange medium changes its temperature over the length of the cooling channel. The wall temperatures for those cavity regions close to the supply are therefore different from those in the return flow region. This difference must be minimized to the extent that its influence on the part quality remains within acceptable limits.

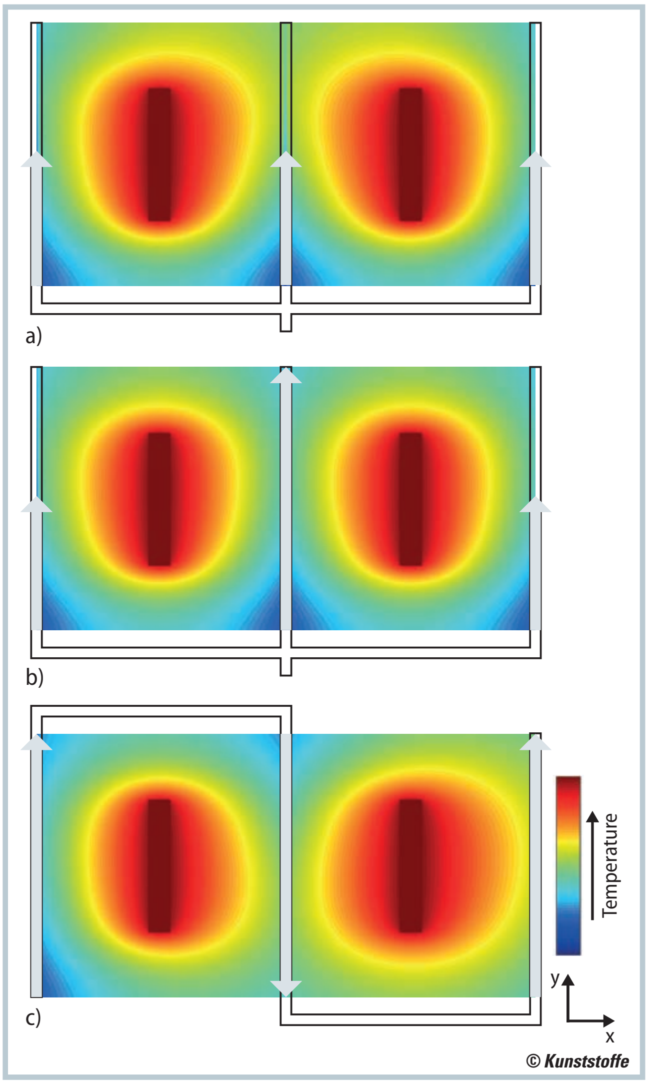

Fig. 1. Simulated heat distribution in a mold with two cavities and three temperature control channels. The arrow directions indicate the flow direction of the heat-exchange medium; the arrow lengths represent the flow rate (source: Engel)

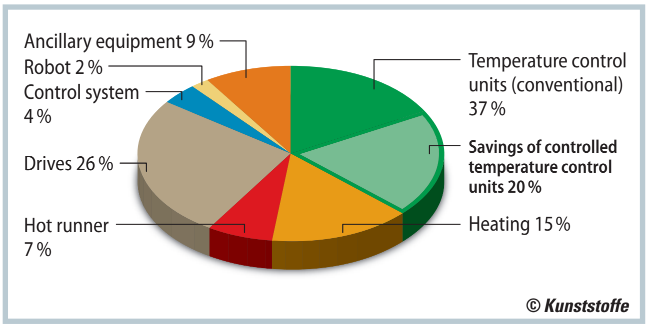

Fig. 2. With the automatic rotary speed control the total energy consumption of the injection molding system can be reduced by 20 % (source: Engel)

The heat-exchange medium temperature at the supply and return ends of a cooling channel can be measured to determine the temperature difference (ΔT). It is a measure of the uniformity of the temperature distribution in the mold, and therefore, unlike the flow rate, is an important quality parameter. The literature [2] discloses guide values for recommended maximum temperature differences (see also the **box "Practical Benefits"**, p. 5). Controlled water manifold systems, such as the Engel e-flomo, offer the possibility of optionally separately controlling the flow rate or the temperature difference for each circuit. The advantage of the ΔT control is that the individually required flow rate is adjusted automatically for each cooling circuit.

The temperature difference is a universal parameter – the same settings can be chosen for both small and large molds. The sensors must be positioned as close to the mold as possible in order to measure the temperature difference that has actually occurred in the mold – not only after the water has cooled down in long hoses. Consequently, the measurement of the temperature difference in the temperature control unit is only of limited significance. It is advisable to perform the measurement in a water manifold that is mounted as close as possible to the mold.

As shown by a thermal simulation (**Fig. 1**), the water is heated along its flow direction, and consequently the temperature in the mold also increases. This effect is reduced with increasing flow rate. Depending on the setting of the temperature control system, differences occur in the heat distribution.

Parallel connection of the three cooling circuits **with the same flow rates**: The common assumption that identical flow rate settings result in the same conditions does not apply here. The water is heated more strongly in the central cooling channel than in the two outer channels, since it picks up heat from both cavities. The parts in the two cavities are therefore hotter towards the center of the mold than at the left and right edges of the mold (**Fig. 1a**).

Parallel connection of the three cooling circuits **with the same temperature differences**: The flow rate in the center channel is automatically doubled, heat is removed as required. Both mold cavities are therefore cooled more uniformly (**Fig. 1b**).

Series connection of the three cooling circuits: The fluid temperature at the entrance to the second and third channel respectively corresponds to the exit temperature from the previous channel in each case. Different temperatures occur around the mold cavities. The temperature distribution is more irregular than for parallel connection. This effect can only be reduced by increasing the flow rate (**Fig. 1c**).

For the heat exchange medium to be distributed as needed in the individual circuits, the flow rates in the manifold must be individually throttled. At the same time, the pump of the temperature control unit runs at its nominal speed. It thus works against the resistance of the water manifold. In these cases, the "braking" of the flow causes energy losses. It is comparable to driving a car with the gas pedal full down, while regulating the speed with the brake pedal.

Configuration	Schematic view	Circuit	Flow rate [l/min]	Pressure difference [bar]	Rotary speed [1/min]	Pump wattage [W]
Individual circuits	5 l/min 40 °C 43 °C	A	5	0.1	1000	151
	5 l/min 40 °C 43 °C	B	5	0.7	1390	188
Parallel connection	10 l/min 40 °C 43 °C 40 °C 43 °C	A	5	0.7	2050	380
		B	5			
Series connection	10 l/min 40 °C ≈ 41.5 °C 43 °C ≈ 41.5 °C	A+B	10	3.4	2950	802

© Kunststoffe

Fig. 3. Required pump output for temperature control of two circuits with different pressure losses. For better comparison, the flow rates were chosen such that a maximum temperature difference of 3 K is established (source: Engel)

Energy Saving of 20 Percent

A remedy, and therefore a considerable energy saving, can be achieved by using temperature control units with speed-regulated pumps, and actuation of the pump by the injection molding machine, matched to the water manifold settings.

Temperature-control units with speed-regulated pumps have been available on the market for some years [3]. However, it is difficult for the operator to set the required speed. Aids are offered, e.g., with recommended values for the flow rate or temperature difference. If a temperature difference is regulated on the temperature-control unit, there is, as described above, the disadvantage of the long hoses as far as the mold, and the resulting increased heat losses. The temperature differences that are measured thus have only limited relevance to the process.

When a downstream water manifold is used, there is little point in controlling the temperature difference in the temperature control, since a mixed temperature from all the manifold circuits is being controlled here. This does not say anything about the temperature conditions in the individual mold circuits.

The temperature control solution from Engel, consisting of the e-flomo cooling water manifold and the e-temp temperature control units from HB-Therm (**Title figure**) has the advantage that the iQ flow control software automatically optimizes the interplay of both components. If the manifold is operated in one of the modes flow-rate control or temperature difference control, the injection molding machine control unit automatically controls the pump speed to the minimum required value. The trick here is that the hydraulic resistance in the manifold is reduced. The valves are opened as far as possible, while the speed is simultaneously reduced. However, the flow rates in the mold circuits remain unchanged by virtue of the smart control. The reduced speed of the pump inevitably reduces the energy consumption.

The temperature control units generally account for a considerable proportion of the overall energy consumption of the injection molding unit. This usually results not from the required heating consumptions, which is mainly required in the lower temperature range (< 70–80 °C) during production start-up, but from the power consumption of the pump, which, with conventional systems, runs with a constant high speed.

For example, the energy consumption of an injection molding production cell is measured (**Fig. 2**). Sample parts with shot weights of 7.1 g each were produced from ABS on an Engel e-motion 170/80 TL all-electric injection molding machine with two integrated e-temp H8-100 temperature control units. The cycle time was 10 s. The supply temperature was 50 °C. In normal operation with speed control switched off – the temperature control units were responsible for 37 % of the total energy consumption. The activation of

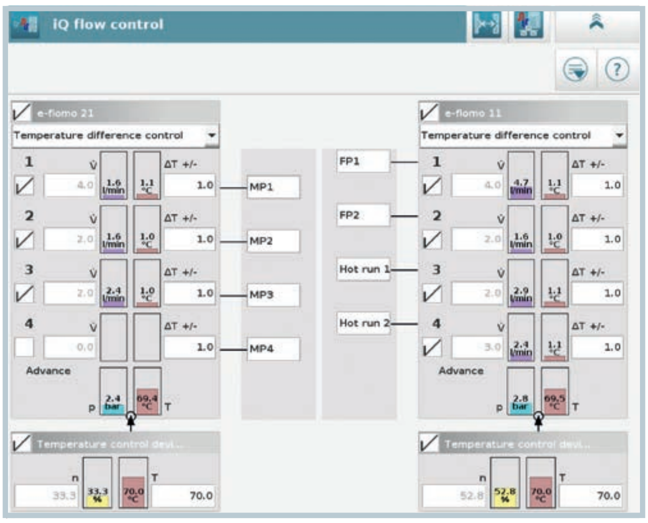

Fig. 4. To make the system, comprising temperature-control unit and manifold, clearer, a new user interface was developed. All the temperature-control components are grouped together on one page: The mold with its cooling circuits, which is shown symbolically, is located in the center (© Engel)

iQ flow control reduced the energy consumption of the temperature control units by about half, without the flow rate having changed. For the overall system, this means an energy saving of 20% with no change in production conditions.

Temperature Control Units and Water Manifolds in Duet

Figure 3 shows the measured pump output for temperature control of two circuits with different pressure losses, with single circuit mode, and series and parallel connection.

- The single circuit tubing requires the lowest pump output overall. However, it requires a separate temperature control unit for each circuit.
- The parallel circuit only requires slightly more pump output; however one temperature control unit less is required because of the use of the water manifold.
- In order to achieve the desired temperature difference of 3K with the series circuit, a flow rate that is twice as high is needed, since heat from the two temperature control channels must now be removed with only one supply. Because of the high flow rate that is required and the longer distance that the heat-exchange medium has to cover, the pressure loss is significantly higher.

Ultimately, the energy consumption of the temperature control unit is over twice as high for the series circuit as for the parallel circuit.

An Overall View

The temperature control unit and water manifold are combined as a temperature control system. The logical consequence of this is the representation of the actual values in one overall view (**Fig. 4**). That makes set-up, monitoring and troubleshooting easier for practitioners

On the overview page, those components that are assigned to the stationary platen are shown at the right, while those on the moving platen are shown at the left. The associated temperature control units are located below the manifolds. Cooling circuits, manifolds and temperature control units can be switched on and off here. The most important actual values are illustrated; setpoint values can be input directly. If individual components trigger an alarm, this can also be seen at a glance.

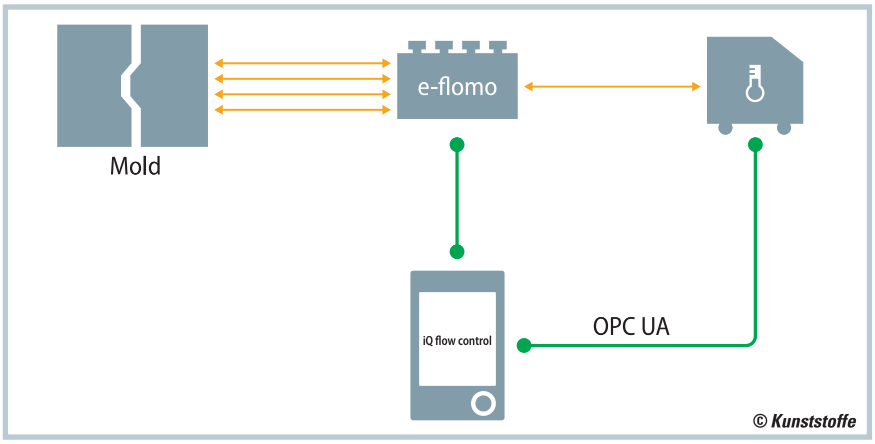

Fig. 5. The e-temp temperature control units from HB-Therm are integrated into the CC300 control system of the Engel injection molding machine via OPC UA. OPC UA is becoming increasingly more popular as the communication standard for the smart factory of the future (source: Engel)

At K2016, Engel presented the new temperature control solution for the first time. The e-temp temperature control units with speed-regulated pump were developed together with HB-Therm. They are integrated, via OPC UA, in the CC300 control unit of the Engel injection molding machine equipped with e-flomo (**Fig. 5**).

Outlook

OPC UA (open platform communication unified architecture) is becoming increasingly established in the plastics industry for communication between networked injection molding machines, ancillaries, sensors and applications [4]. The industrial communication model permits the platform-independent, powerful, reliable and flexible communication both at shop floor level and with higher-level control systems, such as MES and ERP. OPC UA integration is an important component of Engel's "inject 4.0" platform, and is additionally manifested in Euromap, the umbrella organization of the European plastics and machinery industry, expressed in their recommendations for data exchange via OPC UA.

For the integration of temperature control units, Engel, along with HB-Therm, has now defined a communication model based on the full range of functions of OPC UA. The injection molding machine manufacturer would like to offer this model to other temperature control manufacturers in future. ■

Practical Benefits

Recommended maximum temperature differences between supply and return:
Technical parts, precision parts: 1 to 3K
Standard parts: 3 to 5K

The Authors

Dipl.-Ing. Mathias Schläger is project manager in the process technology development department at Engel Austria GmbH in Schwertberg, Austria; mathias.schlaeger@engel.at
Dipl.-Ing. Christoph Balka is project manager in the process technology development department at Engel; christoph.balka@engel.at
Dipl.-Ing. Josef Giessauf heads the process technology development department at Engel; josef.giessauf@engel.at

Service

References & Digital Version

- You can find the list of references and a PDF file of the article at ***www.kunststoffe-international.com/2529081***

German Version

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