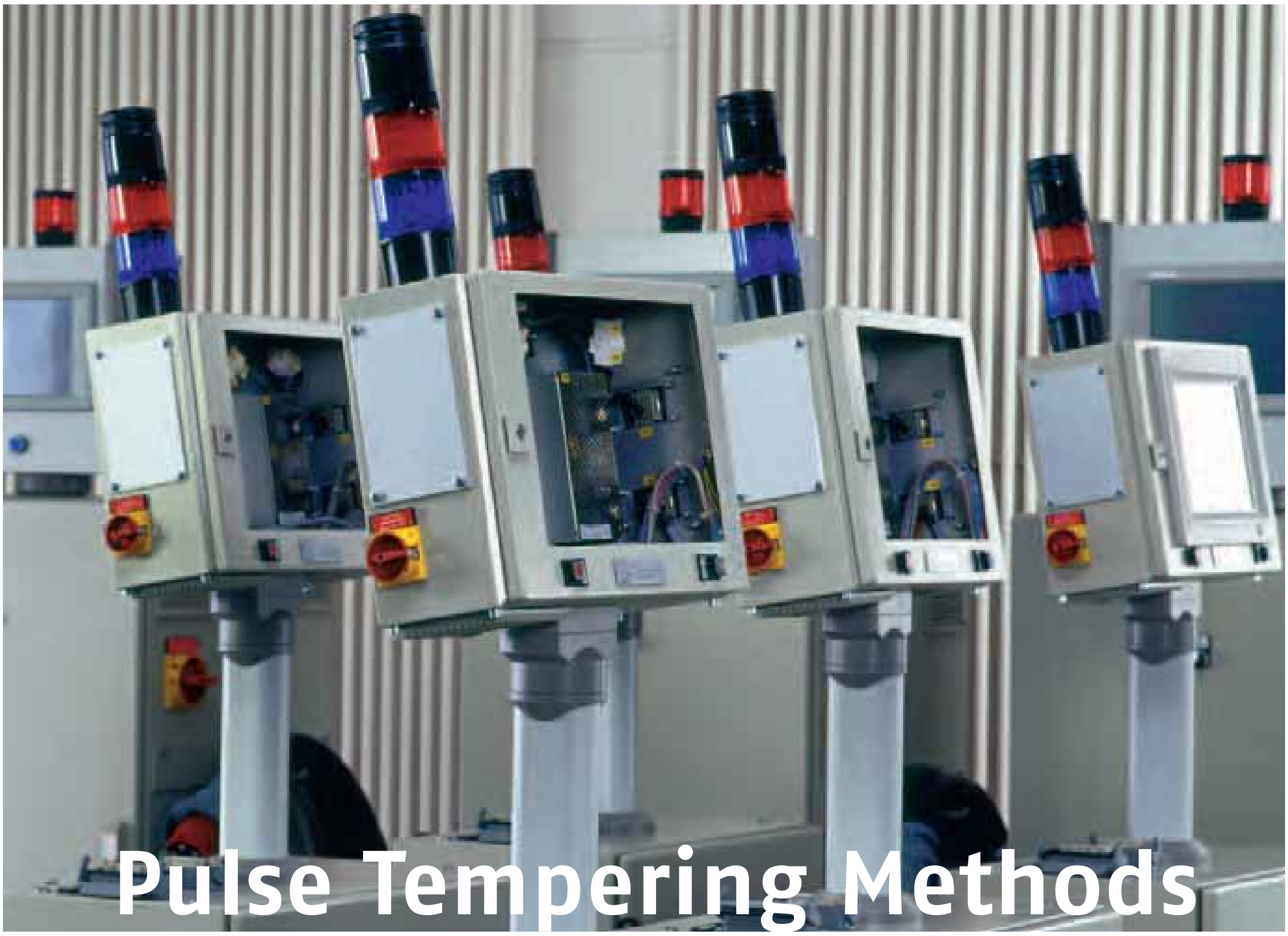

Pulse Tempering Methods

Overall Concept. The realisation of patented pulse tempering technology in injection moulding makes it possible to simplify mould designs, shorten cycle times, reduce energy costs and improve product quality. The significant temperatures, i. e. those of the mould wall, heat-exchange medium, hot runner and mould frame are precisely controlled. The software allows them to be displayed together on the user interface.

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WERNER KOTZAB

The „energy balance in the injection cycle" computer simulation [1] shows that the entire thermal balance in the mould must be considered in order to ensure complete control of the injection moulding process. The generic term „pulse tempering" covers the control of the mould temperatures that play an important role in the injection moulding process. Where the processes are not already known from the literature, the author has newly defined them and quoted the relevant mould temperatures. Fig. 1 lists the equipment modules and beneath them, symbolically, the modes of operation of the temperature control methods offered by the pulse tempering system from Wieder. Fig. 2 shows the temperatures in the mould that can be monitored and controlled in pulse tempering control. The modes include mould wall temperature control (MWTC), mould medium temperature control (MMTC), mould hot-runner temperature control (MHTC) and mould frame temperature control (MFTC).

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The Limits of Pulse Cooling

Conventional pulse cooling is advantageous when the component of the residual thermal energy (Q_R) is greater than zero. The residual thermal energy Q_R represents the difference between the total thermal energy supplied from the melt (Q_M) and external sources (Q_E) and the energy removed by exchange with the surroundings (Q_S). In pulse cooling, the mould wall is usually brought to operating temperature by hot injection. In the processing of expensive polymers, it can be economical to feed hot water through the cooling channels before production start or after a production interruption to achieve the desired temperature. The same applies in principle to the use of electrical heaters for heating up the mould.

As soon as the starting temperature has been reached, with pulse cooling, the system switches over to operation with recooled water or cold air. However, if the thermal energy from the melt and the external energy from the hot runner are not sufficient to keep the mould wall temperatures at the required level, there is no possibility of operating the mould with pulse cooling [2].

Pulse Heating Replaces Multicircuit Control Units

If the injection moulding cannot be ejected when it reaches the demoulding temperature, e.g., because the machine has long non-productive times and the heat loss to the surroundings is consequently greater than the heat supplied by the melt, additional external energy (Q_E) must be supplied to the mould. In pulse heating, the cyclic temperature variation is registered by at least one sensor in the mould wall (MWTC) or in the heat-exchange medium (MMTC). The controller determines the opening times of the valves (type FloValve, see page 4), which produce a precise, cyclical temperature compensation. In pulse heating control, a water heater for one or more machines is used to provide a feed temperature that should be about 10 °C higher than the desired maximum temperature in the mould. If we compare the complicated construction of conventional temperature-control units with the hardware for pulse tempering, we can see that the investment costs for pulse tempering are considerably lower. Other advantages for routine operation are improved product quality and reduced energy costs. In practice, conventional temperature control units are found to generate high costs for maintenance and repair, while pulse tempering operates maintenance free for years. This is mainly the result of the simple hardware required for pulse tempering, which only has a few wear parts.

Pulse heating, too, can be very advantageous for moulds with conformal cooling channels. A ToolMaster K consists of a WPC (Wieder industrial PC) in a protective housing, a control unit and six FloValve control valves. In practice, such an individual unit can replace 6 conventional multi-circuit temperature control units. There are limits to the cycle time reduction that can be achieved. With this mould design, relatively high heat-exchange medium temperatures are necessary to avoid too-rapid heat removal and also avoid uneven temperatures in the cavities.

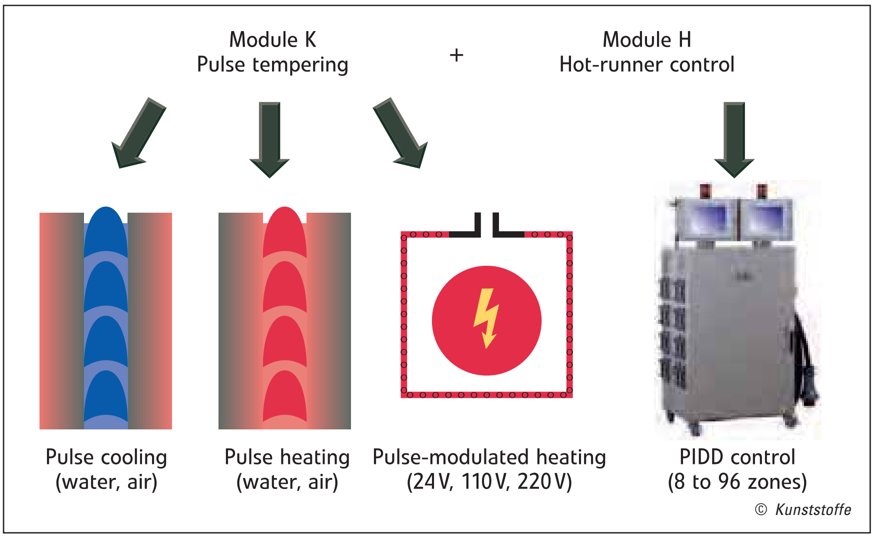

Fig. 1. The various pulse tempering modules and their mode of operation (pictures: Wieder)

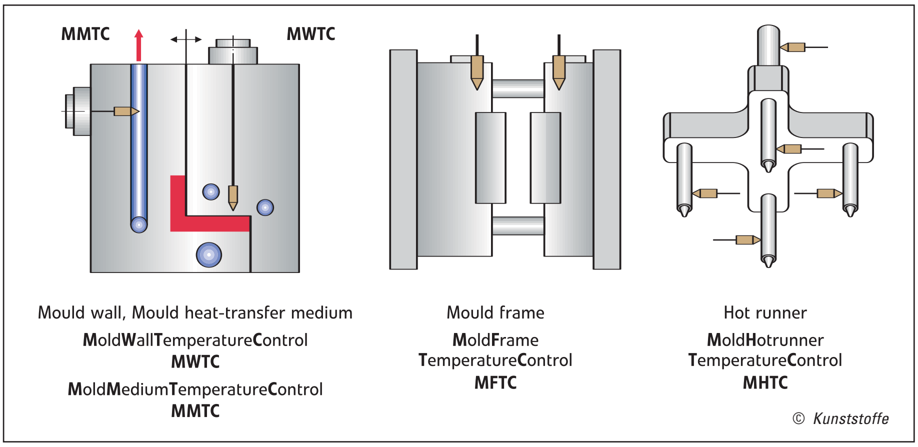

Fig. 2. The significant temperatures in the injection mould are those of the mould wall (MWTC), mould medium (MMTC), hot runner (MHTC) and mould frame (MFTC)

Pulse-modulated Heating and an Advantageous Combination

Pulse-modulated heating has proven its worth particularly at high mould temperatures and is also used for mould frame temperature control (MFTC). The technology includes module K, with NTC and Pt 100 sensors, and module H with type J thermocouples (Fig. 1). Electric heaters with 24 V, 110 V and 220 V input are available. For the mould exterior, Wieder offers plate heaters and frame heaters, and, for the interior, tubular heaters and heating cartridges. Pulse-modulated heating can also be advantageous if a partially increased temperature is required in the mould. This gives the melt in the cavity assisted flow, for example to shift a weld seam or reduce it to the extent that it is no longer visible.

The combination of pulse cooling and pulse heating offers completely new possibilities for temperature control in the mould [3, 4]. As Fig. 3 shows, pulse cooling is applied with a feed temperature of 10 °C to rapidly remove heat from the cavity. To compensate for high heat loss to the surroundings, pulse heating with a feed temperature of 70 °C is used simultaneously. In pulse tempering, pulse cooling and pulse heating can be controlled by one and the same temperature sensor. The control sensor corresponds to a master valve whose opening times can be used to control up to seven slave valves. A combination of pulse-modulated heating with pulse cooling has particular advantages at high mould temperatures, where air is preferably used as coolant to remove the heat energy.

Control of Important Temperatures

Mould Hot-Runner Control (MHTC): The effect of external energy from the hot runner on the thermal balance become clear when small-volume parts are produced. In these cases, the external energy

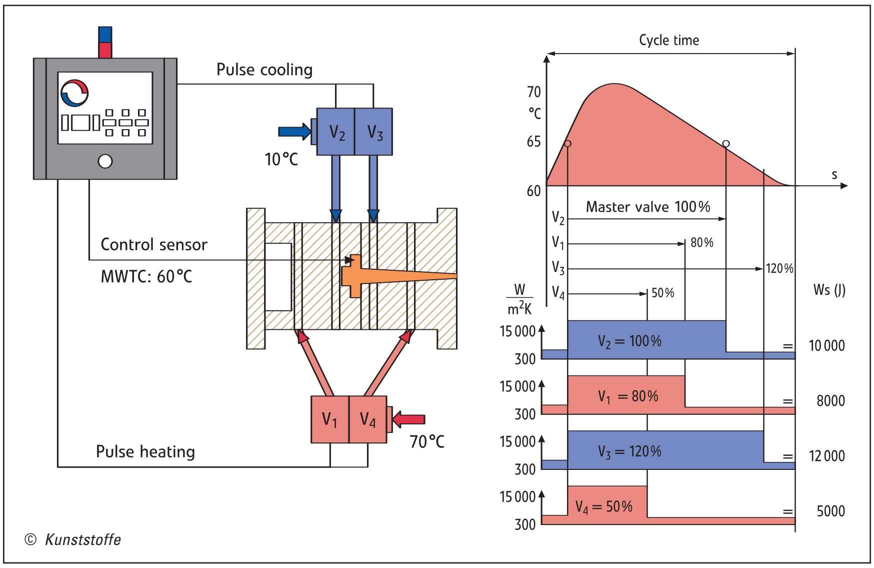

Fig. 3. Left: mode of operation of the combined pulse temperature control; right on the top: temperature distribution at the mould wall; right on the bottom: effects of the valve opening times on the heat transfer

from the hot runner often exceeds the thermal energy from the melt. The logical consequence was therefore to combine pulse temperature control and hot-runner control in one unit [5]. The ToolMaster with Module H offers PIDD hot-runner control, which has a proven track record. With the new generation of the ToolMaster, Wieder has met the demand by many users for an open software concept. The ToolMaster run under the Windows XP operating system on a touch-screen Wieder PC (WPC). Thanks to the multitasking-capable operating system and the possibility of communication via the com port or Ethernet, third-party products can also be integrated into the hot-runner control. The common WPC monitor serves for visualisation of the process for all the connected modules and the third-party product.

Mould Wall Temperature (MWTC) and Mould Medium Temperature (MMTC): In the process development, the main focus was on control of the mould wall temperature, with a sensor mounted 2.5 mm behind the cavity serving as the preferred instrument for dynamic temperature measurement. Control of the mould medium temperature has proven itself chiefly for old moulds and for the processing of polyolefins. New, improved sensors and the control steps of 0.1 °C in the new controller generation now ensure cyclical heat removal even for small-volume parts.

Mould Frame Temperature Control (MFTC): Temperature measurements on hot-runner moulds during heating confirm that up to 30 % of the nominal power of the electrical hot-runner heater is transferred to the mould as heat. When the mould is open, the heat remains at the stationary mould half. While production is running and the mould is closed, part of this energy is conducted into the moving mould half. In the event of an interruption, this has the consequence that the temperature rises at the stationary half and consequently drifts away from the temperature at the moving mould half. A mould with a spacing of 600 mm between the tie bars undergoes a dimensional change of 0.07 mm at a temperature difference of only 12 °C. The consequence is wear, not only in the guide elements but also at the vertical flash faces and in the guides of the shaping cores. This widely recognised problem is solved at its origin by MFTC, which uses temperature sensors in the mould frame region for monitoring and control. A corresponding triggering of electrical heating elements compensates for the deficit in heat energy. Even when the mould is open during an interruption, drifting of the temperature can be eliminated as a cause of mould wear.

Practical Example: Two-component Mobile Phone Faceplate

An analysis of the injection mould designed for the Maguro mobile phone faceplate (Siemens) with the C-Hetco program showed that the cycle time could be reduced by over 65 %. To provide a homogeneous temperature profile in the cavity, the cooling channel arrangement was optimised by the C-Hetco method [6], with only about 50 % of the available cooling channels being utilised. Fig. 4, left, shows the cooling channels before and after optimisation. In the right-hand view, „X" represents the calculated distance between the mould wall and the

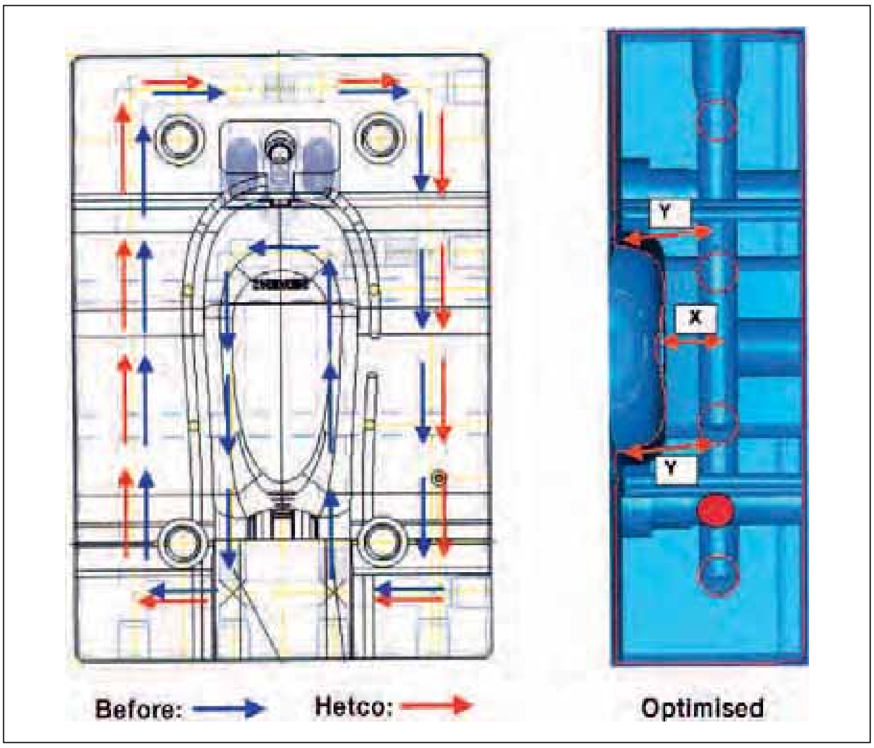

Fig. 4. Comparison of the arrangement of the cooling channels before and after optimisation with C-Hetco

cooling channel, which ensures that the heat transition Q_R in the cooling channel takes place simultaneously with the heat transfer from the melt into the mould wall and before ejection is complete. To avoid hot spots in the mould, the maximum distance „Y" between the mould wall and the cooling channel is completed with the heat transition Q_R into the cooling medium at the end of the cycle.

Finally, the production line is equipped with a ToolMaster – in this case a Module K pulse cooling for MWTC and pulse heating with electrical heating elements for MFTC, and a Module H with eight-zone PIDD hot-runner control MHTC in the IP54 switch cabinet – which controls the temperature of the mould wall, the hot runner and the mould frame (Fig. 5). As further components, four temperature sensors for the MWTC, two temperature sensors for MFTC and two heating tubes are incorporated into the mould of Oechsler AG, Ansbach/Germany. Electrical connection to the temperature sensors and the heating frame for MFTC is made via the sliding contacts of the turntable from Polar-Form GmbH, Lahr/Germany. The huge cycle time reduction is gained to a remarkable extent from the short non-productive times of the K-Tec 110-2K injection moulding machine (manufacturer: Ferromatik Milacron Maschinenbau GmbH, Malterdingen/Germany) and the rapid part removal by the robot system of Ilsemann Automation, Bremen/Germany. The C-Hetco simulation for the injection moulded part and mould is confirmed. The bottom line is a reduction in cycle time from 18.2 to 5.8 s – for the same part quality.

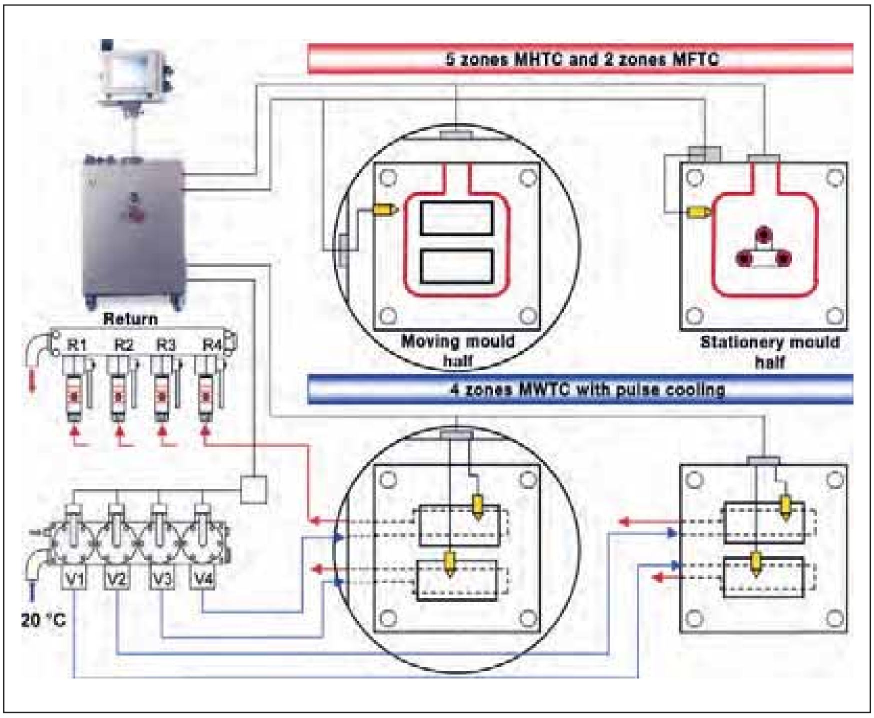

Fig. 5. Functional diagram of the hardware for the example of a two-component mobile phone faceplate

Fig. 6. „FloValve" control valves module (top) and return lines module with flow-rate indicators (bottom)

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New Valve Generation

The new FloValve control valve from Wieder was used for the Maguro mobile phone faceplate. Because these valves are made of metal, they can also be used for pulse heating with high heat-transfer medium temperatures (Fig. 6). The flow-rate indicators are installed in the return lines. The response times of the valves are then considerably shorter, and the precision of the control is greater. The new valves can also be used for blowing out the cooling channels.

Pulse tempering can be used for all known polymers. It brings zero-defect production within reach. A manufacturing cell of this kind with integrated camera monitoring of part quality will be described in one of the following editions. ■

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