Improving of process efficiency in plastic processing:

New valve technology for temperature control units

White Paper
August 2011

Improveing of process efficiency in plastic processing

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In injection moulding, meeting the increasing requirements concerning the surface quality and dimensional accuracy poses a real challenge. Processors demand tension-free and non-deforming workpieces that provide excellent moulding ac-curacy and seamless perfect surfaces in high polish quality. Since the early 1990s, the main innovation driver has been the microsystem technology with its demand for micro components. While moulding accuracy remains the main concern, the focus has gradually shifted towards improved surface quality, dimensional accuracy and efficiency. These requirements were the driving forces for the initial development of variothermal temperature control. Innovative mould technologies and valve designs have enabled manufacturers to opt for efficient variothermal temperature control in serial production, introducing the technology in the automotive and consumer goods industries, including the production of flat screen TVs.

In order to meet the three core requirements of flawless surface finish, high mould accuracy and short cycle times, all components of the injection moulding system must be optimised in a coordinated approach. Apart from choosing the right material, a mould technology with integrated cooling channels and a temperature control method that allows for fast heating and cooling of the mould are part of the solution.

Variothermal temperature control of moulds

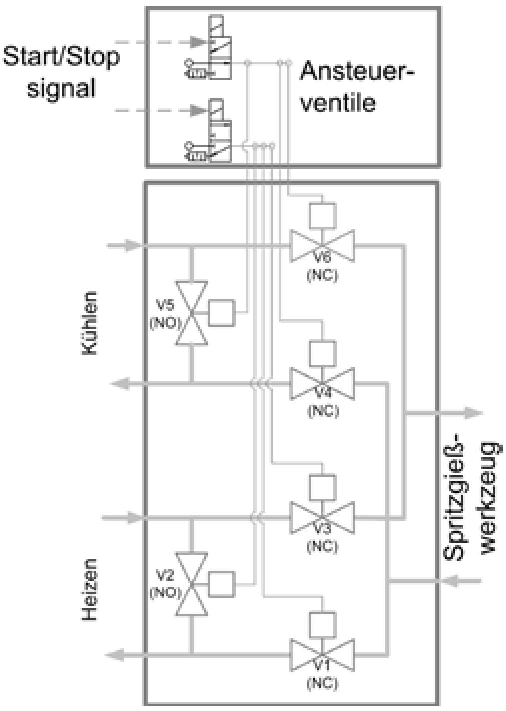
In contrast to conventional temperature control where the temperature of the medium is held at a constant level, variothermal temperature control allows for controlled temperature changes during the injection cycle. At the time of injection, the temperature is about 10 to 30° C above the glass transition temperature of the injected material. After injection, it is quickly lowered to demoulding temperature.

With this technology, it is possible to produce plastic parts with high-gloss surfaces free of flow lines, seam marks and deformed sections. There are currently several systems for variothermal temperature control available in the market. Depending on the chosen technology, the fast heating of the mould is achieved by

- inductive heating in electromagnetic alternating field[1]
- Infrared heating of mould contour
- Laser heating[2]
- Heating with ceramic heating elements located near the mould cavity[3]
- Heating with hot water[4] or
- Heating with steam[5]

All above methods feature fast cooling to demoulding temperature by means of liquid cooling.

Temperature control by means of water or steam is the most widely used technology today. Figure 1 shows an examble of a process diagram for variothermal temperature control with liquid media. They require two separate temperature control units for heating and cooling respectively. The heating circuit is used to heat the mould wall to the glass transition temperature of the plastic material. After injection, the cooling circuit reduces the plastic temperature to a level below the de-moulding temperature. A valve station located between the tool and tempering unit switches between the circuits. During the heating phase (Valve V1 and V3 is opened, V2 is closed, V4 and V6 is closed, V5 is opened), hot medium with a temperature of up to 200°C flows through the mould, while the cooling medium is fed through the bypass valve (V5). During the cooling phase (Valve V1 and V3 is closed, V2 is opened, V4 and V6 is opened, V5 is closed), the cold medium is fed through the mould, while the heating medium is fed through the a bypass valve (V2). In standby modus both temperature control units can run in bypass by opening V2 and V5 and closing V1,



Flow schematic for switching between heating and cooling for variothermal control

[1] Th.Walter: Geräte und Verfahrenstechnik zur induktiven Werkzeugtemperierung beim Mikrospritzgießen. University of Stuttgart, IKFF, Dissertation, 2003
[2] W.Michaeli, F.Klaiber, M.Schöngart: Variotherme Temperierung mit Laserstrahlung: Kunststoffe 08/2010, pages 66-70.
[3] H.Gries: Kühlen und Temperieren mit System – Thermische Prozessführung sicher beherrschen: Kunststoff-Berater 9/2010.
[4] K.H.-Gruber: Heiss macht schön. Plastverarbeiter, July 2008
Stefan Hofmann: Matt oder Glanz – Ohne Lack. Plastverarbeiter, May 2010

V3, V4 and V6.

This method has two distinct advantages: It can be implemented at low cost with existing moulds for testing and quality improvements are immediately visible. As the cycle times need to be adjusted, it is however necessary to modify the mould technology and the design of the cooling channels.

Temperature near the mould contour

Over the last few years, new production technologies with temperature control channels located close to the mould contour and cavity have been developed. This allows for faster and more efficient thermal transfer between the medium and the material in the cavity during heating as well as cooling. These mould technologies are commonly referred to as „segmented mould temperature control“[6] or „lasercusing“[7] [8]. In the past, short cycle times could only be achieved at the expense of workpiece quality. By combining near-contour channels with variothermal temperature control, this problem has been solved and it is now possible to produce perfect workpieces with short cycle times. In many cases, the workpiece quality could even be improved with this new method.

More cooling channels, less flow

As regards the number of cooling channels, the following rule of thumb applies: The more cooling channels in the mould and the closer the cooling channels to the cavity, the more accurate the temperature control. This can however only be achieved by controlling the temperature in each cooling channel separately. This obviously has implications for the design of the injection moulds and the tempe-rature control devices:

- The number of cooling channels must be increased.
- The cooling agent flow through each channel drops in some cases to a level below 0.3 l/min.
- The peripheral equipment (e.g. valves and sensory devices) for the temperature control of the moulds must be adjustable to suit the number of cooling channels.

[6] N.Küls: Ganz nah dran. Plastverarbeiter März 2009
[7] F.Herzog: Lasercusing ermöglicht konturnahe Kühlung in Werkzeugkernen und –einsätzen. Maschinenmarkt 10/2007
[8] ATT-Broschüre: Variotherme Flüssigkeitstemperierung von Spritzgießwerkzeugen mit oberflächennahen Kühlkanälen.

Innovative adapted valve technology

A key component for the reliable implementation of variothermal temperature control is the valve station installed between the tempering unit and the inje tion mould. The valve station must meet the following requirements:

- Max. temperature load of 200 °C
- Temperature change cycles of $\Delta T \approx 150$ °C
- Max. pressure of 16 bar
- No mixing of cold/hot cooling medium in the tempering units
- Low medium volume between valve station and mould
- Extendable according to the number of cooling circuits
- Compact design
- Installation close to or integration into injection mould
- Resistant against contaminated tempering media

Buerkert has developed a new modular valve system designed for variothermal temperature control that can be flexibly adjusted to suit the specific system requirements. Figure 2 shows a 6x valve block consisting of six individual valves that can perform all the functions shown in figure 1. This block can be simply combined with a hot and cold water tempering unit to implement a variothermal temperature control system for injection moulds. The six pneumatically actuated valves are controlled through a pilot control block that switches the valves from hot to cold medium flow and vice versa depending on the actual injection cycle. The valve block switches between three statuses:

- Idle: bypass valves V2 and V5 open, V1, V3, V4 and V6 closed

- Heating: Valves V2, V4, V6 closed, V1, V3 and V5 open

- Cooling: Valves V1, V3 and V5 closed, V2, V4 and V6 open

6x size DN10 valve station for variothermal tempering

At the core of the modular design is the basic module with eight connections consisting of a cross manifold and a compact pneumatic actuator with an actuator size of 30mm and a nominal diameter of DN10 made in stainless steel. Depending on the customer requirements, the basic modules are machined to provide the necessary fluid channels and assembled into compact units. If required, the basic modules can be equipped with flow, pressure and temperature sensors. Figure 3 shows a 3x manifold with a temperature sensor in the inlet pipe and a flow sensor in the outlet connection. Thanks to the modular design of the components, this concept caters for virtually all configurations. By combining different components, any desired solution can be implemented.

3x manifold with flow rate and temperature meter

6x size DN20 valve node for variothermal tempering

For flow rates that require a nominal diameter greater than DN10, Burkert has developed a housing concept for DN20 and DN25 that is of a similar modular design. In contrast to the DN10 model, the basic housing is designed in such a way that it can be welded with standard orbital welding clamps to implement the solution required by the customer. For DN20 and DN25, Burkert uses pneumatic actuators from its tried and tested ELEMENT range. This ensures that any improvements made to the Buerkert standard range are automatically incorporated in all custom-engineered solutions.

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