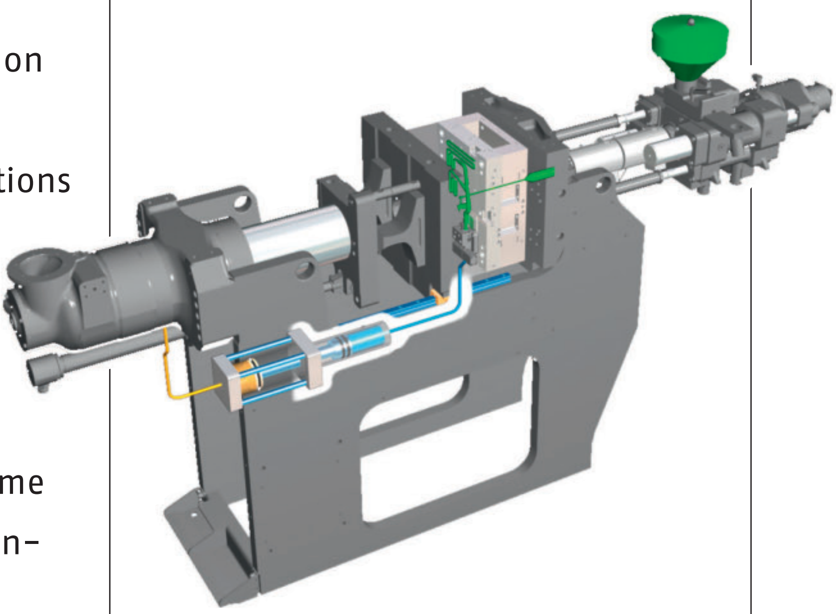
Molded Parts with a Hollow Core. Water injection technology in injection molding allows the manufacture of molded parts with hollow cross-sections and is used in particular when such parts cannot be produced by blow molding or conventional injection molding techniques, i.e. using cores or slides. For the first time a new process integrates the water injection entirely within the injection molding machine via an additional injection unit.



The piston injection unit with a pressure intensifier is mechanically integrated into and controlled by the injection molding machine

Water Injection via an Additional Injection Unit

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Water Injection Technology (WIT) is a special injection molding process that the Institute of Polymer Processing (Institut für Kunststoffverarbeitung – IKV) at RWTH Aachen University has been developing since 1998 [1]. After the injection of polymer melt into the cavity water is injected via an injector that displaces the fluid melt core from the center of the component. In this way a cavity is created inside the molded part. Towards the end of the cycle the water is removed from the cavity.

The process is identical in many respects to the long established gas injection technology (GIT) where nitrogen is used as the cavity creating medium. GIT and WIT are brought together under the umbrella term of fluid injection technology. Furthermore the process shows similarities to co-injection, also referred to as sandwich injection molding, where two components are injected one after the other into a cavity.

Using fluid injection technology molded parts such as handles or media ducting, even with complex geometries, can be produced in a single stage process. In comparison to gas as the fluid, water has the advantage that it provides additional cooling for the interior of the part. Cycle times can thus be significantly reduced in comparison to GIT. For this reason WIT in particular is the preferred choice for parts with large cross-sections, for example handles. Additional advantages can be seen in a smoother internal surface and a more uniform wall thickness distribution. This means that WIT is ideally suited for the manufacture of media ducting and piping. Many automobiles are already equipped with tubes for the oil dipstick made using this technology [2].

Polypropylene (PP) and glass fiber-reinforced polyamide (PA 6 und PA 66) are most commonly used for water injection. The latter displays higher strength and heat distortion resistance whilst PP allows a better internal surface to be produced. A combination of co-injection and WIT is particularly suitable for the man-

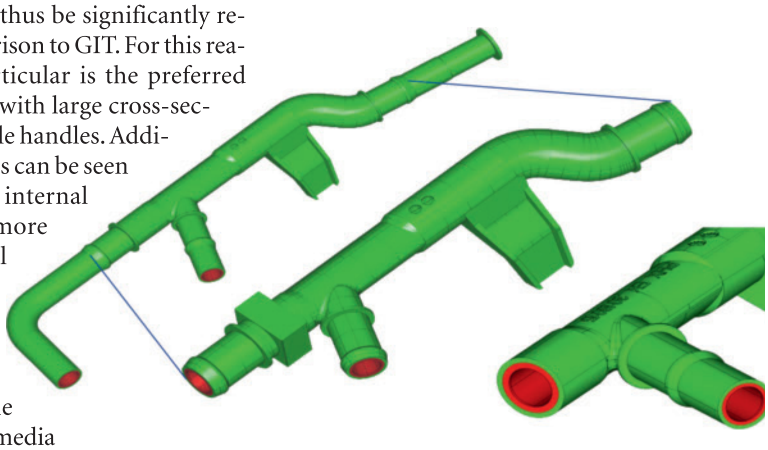

Fig. 1. The multi layer medium conduit is manufactured using a combination of a co-injection and water injection process

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ufacture of under the hood media ducting in automobiles as this allows the advantages of these materials to be combined with each other (Fig. 1).

Three Process Variants and the Corresponding Machine Technology

As with gas injection there are three possible process variants.

Overflow Process: The cavity is completely filled with polymer. Through the opening of a shut-off valve the melt can flow into a secondary chamber as it is displaced from the core of the molded part by the inflowing water. This variant generally delivers the best surface finish.

Short Shot Process: The cavity is only partially filled with polymer, complete filling of the mold occurs at the same time as the formation of the hollow core by the water. However, halting the melt front during the transition from injection of the polymer to injection of the water means that it is possible that changeover marks will be visible. The advantage of this variant is however that no material is lost in the secondary chamber.

Melt Pushback Process: As with the overflow process the cavity is initially fully filled, the melt is however then pushed back into the space in front of the screw by the water and used during the next cycle. Only material with sufficient thermal stability should be used for this process.

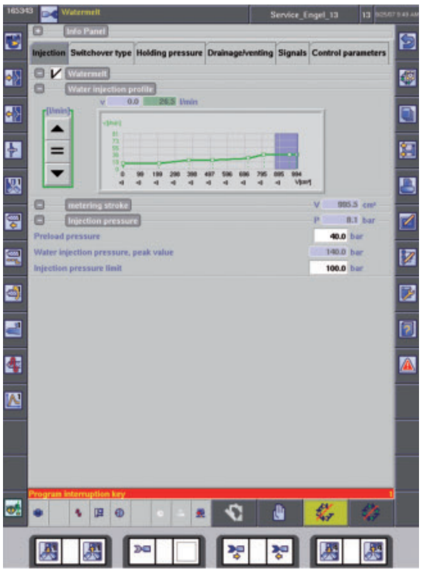

Fig. 3. In terms of control systems water injection is analogous to melt injection

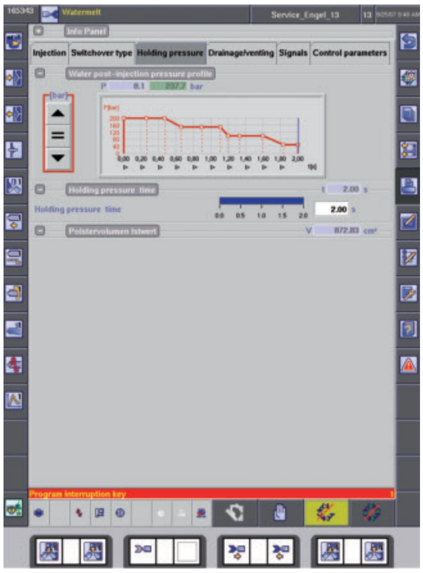

Fig. 4. In the second, pressure controlled phase in order to compensate for the shrinkage of the polymer a holding pressure is maintained in the water (pictures: Schneegans, Engel)

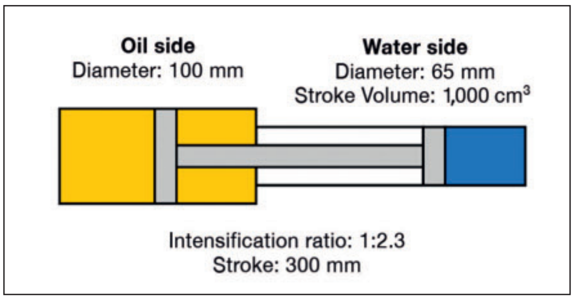

Fig. 2. Schematic representation of the pressure intensifier. In this configuration pressures up to 300 bar are possible, the maximum volume is 1 l

In order to increase the cooling effect still further the so-called flushing process can be used for all three variations. This involves the part being flushed with water via a second injector which removes large quantities of heat. The prerequisite for the use of this process variant is a reliable machine technology that allows a precisely controllable and reproducible process.

Gas injection is generally run with pressure control. However water, unlike the nitrogen used as inert gas in GIT, is a practically incompressible medium. This property allows an exact control of the volumetric flow rate via a pump with rotational speed control or a pressurized water generator with a control valve or a piston injection system [3]. A piston injection system with integrated travel measurement allows precise control across a wide range of volumetric flow rates. The manufacture of the part shown in Figure 1 with a weight of approx. 100 g requires 60 cm^3 of water. For an injection time of 5 seconds this equates to a flow volume of 0.7 l/min. Particularly in the case of these small volumes/volumetric flow rates the piston method has the inherent advantage that it can be precisely measured.

An Injection Molder with Integrated Piston Injection System

Engel Austria GmbH has now produced the first water injection system with a piston injection unit (type: Watermelt) integrated directly into the injection molding machine (title picture). This is located in a part of the machine frame underneath the clamping unit. The arrangement does not require any additional space next to the injection molding machine and the distance between the injection piston and the mold is so short that pressure losses are reduced to a minimum.

The piston injection system functions as a pressure intensifier from oil to water. The oil side is connected to the machine's hydraulic system and the water side is connected via the injector to the mold. A piston rod between the two sides of the pressure intensifier ensures that the media are completely isolated and prevents water getting into the hydraulic system and vice versa.

The maximum water pressure is determined by the area ratio of the pressure intensifier. For example if the area of the oil side piston is twice that of the water side one then the pressure available for the water injection is double that of the hydraulic pressure of the injection molding machine. However, this means that twice as much oil has to be pumped into the pressure intensifier as the amount of water used on the other side for forming the hollow core (Fig. 2).

In order to ensure a long service life for the equipment it is necessary to pay particular attention to the quality of the water. The following values are recommended for the minimization of corrosion and lime scale build up:

- pH-value between 7 and 8.5,
- Water hardness from 6 to 15° dH, and
- Chloride concentration < 100 mg/l.

Water Injection Process Sequence

Independent of the previously described process variants the process sequence for water injection with a piston injection system can be outlined as follows. To start with, the water side of the pressure intensifier is completely filled with the help of a small pump. At the beginning of the cycle with the injector closed a preloading pressure is built up in the water feed pipes. In this way a defined pressure is immediately available at the beginning of the water injection and at the same time melt is prevented from flowing out of the cavity into the injector. After injection of the melt into the cavity the injector is opened with a time delay. In this time frame the polymer melt progressively solidifies on the cavity wall, which means that this parameter is one of the deciding factors for the wall thickness of the finished part.

In terms of control systems water injection is analogous to melt injection: The first phase, which is responsible for the creation of the hollow core, comprises a velocity controlled advance of the water injection piston (Fig. 3). In the second, pressure controlled, phase a holding pressure is maintained in the water in order to compensate for the shrinkage of the polymer (Fig. 4). A fixed position in the travel of the piston can be used as a changeover criterion between the two phases by which the volume used for the creation of the hollow core can be exactly defined. Alternatively, a pressure or time based changeover can be chosen.

At the end of the holding pressure phase the water pressure is released. It has been found that a gentle release of the pressure is advantageous because this avoids cavitation effects. This pressure release is therefore carried out in accordance with a set of parameters. The remaining water can be let out of the component by opening a valve. Finally all of the piping between WIT unit and the injector is flushed with cold water. This step ensures that in the next cycle neither air nor leftover hot water can get into the part.

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Reproducible Process with Monitoring Function

The water injection sequence with a piston injection system is thus indeed in many respects the same as the injection process of the injection molding machine. It therefore makes sense to integrate the Watermelt control into the main machine control system. The main control elements do not need to be developed from scratch, but rather can be taken from the polymer injection system. Machine operators benefit from the user friendliness and the fact that they can use the existing control infrastructure:

- The user interface for the polymer and water injection are uniform.
- WIT specific parameters are stored in part data sets in the injection molding machine.
- Set point curve shapes such as water pressure and quantity can be shown graphically together with the set points for the melt injection process which makes the optimization process simpler.
- WIT parameters affecting quality are stored in the process data protocol of the machine or displayed in the process data charts.

High resolution travel measurements in the pressure intensifier and pressure measurements on the water side of the piston allow for a precise control of the water injection. The amount of water injected can be determined from the difference between the position of the piston at the beginning and end of the water injection and this can be used to monitor and document the process. Parameters familiar to injection molders such as injection time, changeover position, changeover pressure and material cushion are also available for the assessment of the reproducibility of water injection.

Summary

In process technology terms water injection with the process steps injection, changeover, holding pressure is very similar to the injection of polymer melt. Piston injection via a pressure intensifier resembles the principle of the injection unit of an injection molding machine very closely and can be very precisely controlled. Through complete integration into the injection molding machine both mechanically and within the control system water injection can for the first time be performed with an „additional injection unit". Alongside a small foot print and reduced pressure losses in the piping this system guarantees a simpler operational control and reproducible high quality of the molded parts. ■

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