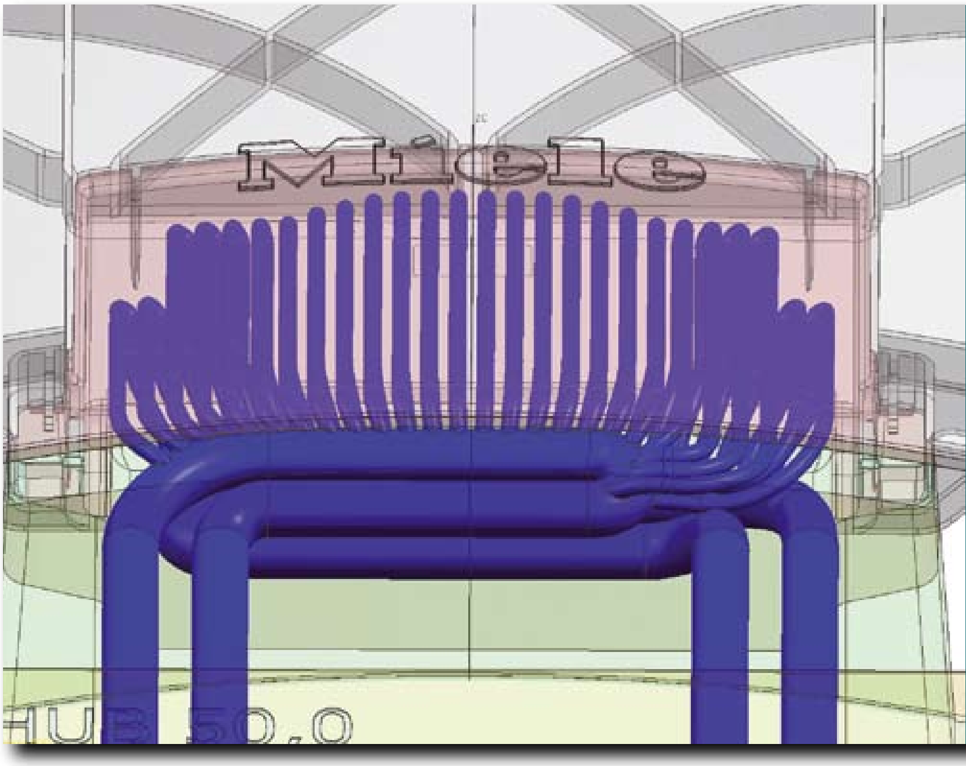

PHOTO: HOFMANN INNOVATION

In the latest instalment in his Moulding Masterclass series, moulding expert **John Goff** turns his attention to what goes on in the mould cavity during the cooling cycle

Rise to the cooling challenge

Appliance maker Miele uses conformal cooling techniques to maximise heat energy extraction rates from its moulds

So far in this series of articles looking at the injection moulding process we have focused on getting the molten material into the mould cavity in the most efficient way. Now we turn our attention to the manner in which the mould tool is opened and closed and the rate at which the molten material solidifies within the cavity, as both are regarded by many as critical for achieving productivity gains.

With particular reference to mould setting, the choice of opening distance and corresponding intermediate values (with their respective speed and force settings) often culminates in time reductions. It is a general observation that mould tool setting procedures vary considerably throughout the industry as the methodology employed differs from company to company. The type of moulding machines present, their size, their make, and the weight and the complexity of the mould tool all contribute to the way in which individual firms approach the mould setting task.

Cooling time, rather than mould setting, is regarded by most as the more significant part of the moulding cycle and for this reason mould setting will be discussed in more detail at a later stage. However, it should be noted at this point that while the greater focus is given to cooling time optimisation, mould movement times do contribute to the overall time available for heat content to be removed and should not be ignored completely. Of course, any time reductions resulting from mould movement optimisation must not be achieved at the expense of safety or long term damage to the surface of the mould tool and/or the moulding machine.

Don't overlook the basics

Converting solid granular plastics material into a molten liquid at uniform temperature requires the input of both conductive and frictional heat energy. And the amount of heat energy required to convert polymeric material from either its ambient or drying temperature to a value where it flows readily and uniformly will vary from polymer to polymer. This heat energy is then transferred from the screw and barrel assembly to the mould tool upon filling the impression to 95-98% fullness and applying holding pressure.

The mould tool can be considered as a heat exchanger where the derived heat energy is absorbed into the mould. This heat content needs to be removed, which is most commonly achieved via the cooling medium flowing within and around the components and plates of the mould tool through machined channels. These channels are normally drilled and thus circular in cross-section. However, mould manufacturing techniques that involve cavities and cores manufactured in

PHOTO: ENGEL/ZAO

Good mould design is the first and a critical step in achieving optimal results

sections and then vacuum brazed allow different configurations and shaped (conformal) cooling channels to be produced.

Heat removal has to be as uniform and efficient as possible to allow the moulded component to reach a temperature at which it can to be ejected without risk of distortion or change in shape. When the molten plastic touches the colder surfaces of the core and cavity it solidifies and forms a solid skin (referred to as frozen layer). Once the molten material has been delivered into the cavity it takes some time for the resulting moulding to cool to the ejection temperature, and this time is naturally reflected in the overall selected cooling time value. For the heat energy to be removed from the bulk of the moulding it is initially required to pass through the frozen layer in contact with the adjacent metal surface of the cavity and core, then through the thickness of the mould material and finally into the cooling medium passing within the machined channel.

For the heat energy from the molten core to be effectively transferred through the frozen skin, compression against the metal surfaces of the mould tool needs to take place – achieved by application of holding pressure. Practical observations confirm this - processors that mould typical semi-crystalline materials such as acetal, polyamides, polypropylene and high density polyethylene without holding pressure find when undertaking the short shot technique to achieve 95-98% fill that the resultant sunken mouldings are much hotter to handle than when holding pressure has been applied.

As some melt solidification takes place during the holding pressure phase, the sum of both the holding pressure and cooling time values is often regarded as the total time available to allow the heat energy to be removed from the moulding. Naturally the grade and type of the material used to make the mould tool, the cooling medium and associated flow rate passing in and around the mould tool has a considerable influence on the selected cooling time value. Furthermore, the type and number of mould temperature controllers used for a particular mould tool plays a role in achieving the fast heat removal rates required to obtain low cooling time value selection.

Get mould design right

When designing injection mould tools for manufacture of thermoplastics components, designers often overlook that plastics materials are insulators and poor conductors of heat. In order to increase the rate of heat removal, the use of cooling medium temperatures at or below the recommended values are often employed. This is particularly the case when the number and design of the cooling channels within the mould is poor. Such temperature values inevitably result in mouldings with poorer surface finish, increased inherent stress levels and that display an increased tendency to deform and warp, particularly with semi-crystalline materials.

Coolant flow rate depends upon the flow channel dimensions – including the length and diameter - the flow characteristics of the cooling medium and the pumping pressure. Naturally, the smaller the channel diameter and longer the flow path of the cooling medium, the greater the pumping pressure required to maintain the high flow rates. To achieve performance improvements and gains in productivity, the heat content entering the mould tool from the molten resin needs to be fully removed during each cycle. Accurate mould surface temperature control is of paramount importance to achieve consistent product quality - it is not sufficient to just consider where the cooling channels are located.

As a rough guide, taking and using a mould temperature controller off-the-shelf without first determining its actual capability with respect to the role it has to fulfil can reduce profits by as much as 20%. More often than not, few technical considerations are given to this extremely important topic of injection moulding technology, which can yield considerable improvements in overall manufacturing productivity and product quality. We will look at this area in closer detail in the next instalment in this series.

About the author

John Goff is managing director of G&A Moulding Technology. This is the eighteenth instalment in the Moulding Masterclass series. You can read the most recent previous articles **here**, **here** and **here**.