The challenges of chilled moulds

In the final instalment in his discussion of process cooling, moulding expert John Goff looks at operating the mould at below ambient temperatures

Previous instalments in this discussion on injection process cooling looked at operating the mould at above ambient temperatures. In this final instalment we consider the use of coolant medium temperatures of less than 25°C, which often calls for a different approach to mould temperature regulation.

Coolant temperatures at or below typical ambient temperatures are frequently used when moulding components in styrenic, olefinic and vinyl-based thermoplastic materials, especially in production of thin walled parts (such as closures, syringes and containers) or thick walled products (pipe fittings, couplings, fascias). Applications include both high cavitation and large single/dual impression mould tools.

One of the major reasons for using these low coolant temperatures is to remove the large amount of heat energy transferred to the mould tool each cycle, so maintaining a constant machine and process temperature. Conversion of polypropylene and polyethylene in particular requires the removal of considerable amounts of thermal energy, as can be seen from the comparative heat energy value figures in Table 1.

It can be seen that polypropylene and polyethylene requires 1.6 to 2.3 times the rate of heat energy to be removed per gram compared to ABS, polystyrene or polyvinylchloride (where UPVC products are being considered it is often the mass of the component that dictates the amount of heat energy that must be removed).

Consider the production of a PP container weighing 12.56g produced on a 32-cavity mould tool at a cycle time of 12 seconds. Such a production cycle requires 21,569.7 joules/second to be removed from the mould on each cycle.

For greater cyclic efficiency, calculations are very often based upon the heat content being removed within 80% of the total cycle time. And very often the amount of heat energy that must be removed is expressed in kilowatts, so in the above previous example it would be 21.57 kW. Remember, however, that this calculated value does not take into account the inherent heat energy being created by any hot runner system or the cooling of the oil in the injection moulding machine, which can be particularly significant in the case of hydraulic machinery.

These values demonstrate the enormity of the heat removal issues associated with fast cycling, high cavitation injection moulding tools and the necessity to

Table 1: Comparative heat energy removal requirement for common polymers (per g of resin)

PP	644 joules
LDPE	597 joules
HIPS	431 joules
HDPE	656 joules
GPPS	406 joules
PC	452 joules
UVPC	276 joules

Note: A more complete listing of heat removal rates for commonly used thermoplastics, together with recommended melt and mould temperature settings, was published in the previous instalment. It can be viewed **here**.

Source: G&A Moulding Technology

maintain appropriate cooling medium flow rates to ensure the variation in temperature between the cooling fluid entering and exiting the mould is no greater than 4°C.

In these applications, high performance, high flow rate pumps providing fluid throughputs of up to 400 litres/minute must be employed. Achieving such flow rates will typically require special high performance couplings to prevent spillage and leakage. Furthermore, if very high coolant flow rates can be achieved and maintained, the base coolant system temperature can be increased to 20-22°C to create less of a thermal shock to the resultant moulding. As discussed earlier in this series, this will generally result in better dimensional stability and end-life service performance.

Regardless of whether you are producing a component on a short or long moulding cycle, energy still needs to be removed. A typical thick wall plumbing component weighing around 1.4kg being produced at a 100 second cycle in UVPC will require the removal of heat energy of 3.86kW on each cycle. Based upon the 80% principle mentioned earlier, the total heat energy removal requirement calculates to 4.83kW. Compared to the 21.57kW required for the container component, this appears a much less challenging task. However, part quality, dimensional control and surface functionality still need to be accounted for when considering the overall cooling capability of the mould tool.

Several approaches can be taken to ensure adequate cooling capability. This article will not review the types of cooling systems available in the range of air/water condensers or evaporator cooling, as this is offered by equipment suppliers and other supporting bodies. In the UK, for instance, the PMMDA produces a leaflet detailing the important aspects involved in selecting the correct cooling requirements for a particular application (this guide can be downloaded **here**).

Today, the use of coolant temperatures of 10°C or less is relatively uncommon due to the cost of cooling the fluid to this temperature prior to introduction into the system and the energy required to pump the more viscous fluid around the mould tool. Operating moulds at such low temperatures also risks considerable corrosion damage to the mould tool surfaces due to excessive condensate formation on its external surfaces. While the use of stainless steel (AISI 420/DIN 1.2083) in place of alloyed (nickel/chromium/carbon) steels provides a solution to rust formation, there is a trade off. The heat removal rate (thermal conductivity value) of stainless steel is one half to one third of that compared of H13 (DIN 1.2344) or AISI (DIN 1.2311) steel.

More importantly, quenching the molten polymer resin with coolant at such low temperatures can greatly affect the mechanical strength, dimensional stability and end service performance of the component due to the interference of crystal growth. This is particularly the case when processing semi-crystalline resins such as PP, LDPE, LLDPE and HDPE. Typically, coolant temperatures in the range from 13-18°C are now used to minimise condensation and reduce the quenching effect.

As has been made clear in previous articles in this series, what is important with any heat energy removal process is the coolant velocity (the flow rate) passing through and around the mould tool. To sustain the necessary flow rates, particularly through narrow or small cooling channels, high delivery pressures are often required. As a result, coolant flow rates are often measured and monitored continuously to ensure the required flow rates are maintained.

It is perhaps appropriate to end this discussion on mould cooling with a summary of the key points covered over the past four instalments:

- Utilise the most effective coolant circuitry within the mould tool;
- Install appropriate connectors and couplings;
- Use independent rather than looped circuit connections;
- Measure coolant temperatures and flow rates continuously;
- Select an appropriately-sized mould temperature controller;
- Calculate the flow rates required to maintain correct performance.

About the author

John Goff is managing director of G&A Moulding Technology. This is the 21st instalment in his Moulding Masterclass series of injection moulding process optimisation articles. You can read the most recent instalments **here**, **here**, and **here**.

The next edition in this series will look at clamp force setting and optimisation. If you wish to be sure you don't miss it, you can subscribe to InjectionWorld for free **here**.