Selecting mould temperature controllers

In this latest instalment on optimising mould cooling, moulding expert John Goff provides advice on mould temperature controller selection

With up to 50% of the typical moulding cycle attributable to cooling time, giving serious consideration to the purchase or specification of an appropriate mould temperature controller is essential for two important reasons: Productivity in terms of cycle time; Sustaining product quality through process consistency and/or capability.

As has been highlighted in previous articles in this series, mould cooling is a relatively complex subject area that is influenced by several aspects of the moulding process.

The manner in which heat energy is removed from each cycle is attributable to:

- The technology utilised within the mould tool
- The manner in which the cooling medium passes through the tool
- The base material used for the mould
- The type of thermoplastics material being processed
- The selected processing conditions for component manufacture.

The investment cost for the mould tool and moulding machine, including robotics and the like, tends to dominate the decision making process in most projects. Much less attention is paid to supporting ancillary equipment such as mould temperature controllers and the chilled water supply, as the cost is insignificant to that of the mould tool and moulding machine. However, poor selection will ultimately affect the component price and related process productivity (an equally important area that again can be overlooked is material conditioning, drying and transportation to the moulding machine, which will be covered in a later article).

The mould temperature controller needs to have suitable heating capacity to obtain the correct mould operating temperature in minimal or specified time. Naturally, this capacity depends upon the size of the mould and the number and arrangement of cooling channels and needs to be taken into account when purchasing the equipment. Very often invaluable production time is lost waiting for the mould tool to reach the correct temperature, so for large moulds pre-warming stations are designated within the moulding division. The mould temperature controller's pumping capacity and ability to maintain a ± 2°C variance (preferably ± 1°C) on the selected cooling medium temperature also needs to be taken into account.

Performance of mould temperature controllers can vary immensely. It is important not to sacrifice coolant

Table 1

Material	Melt temp Range °C	Average melt Temp °C	Mould temp Range °C	Average mould Range °C	Specific heat kCal/kg/°C	Specific heat j/kg/°C	Heat to be Removed kCal/g	Heat to be Removed j/g
ABS	220 to 280	240	40 to 80	60	0.4657	1950	0.0838	351
ASA/AAS	245 to 280	260	40 to 80	60	0.5278	2210	0.1056	442
CA	200 to 230	215	40 to 80	50	0.4992	2090	0.0824	345
CAB	200 to 230	210	40 to 80	50	0.4992	2090	0.0799	334
CAP	200 to 230	220	40 to 80	50	0.5183	2170	0.0881	369
ETFE/FEP	300 to 380	350	200 to 230	220	0.3845	1610	0.0500	209
GPPS	180 to 260	220	13 to 60	20	0.4849	2030	0.0970	406
HDPE	185 to 270	230	13 to 70	30	0.7834	3280	0.1567	656
HIPS	190 to 280	225	13 to 75	20	0.5016	2100	0.1028	431
LDPE	170 to 260	210	13 to 40	20	0.7500	3140	0.1425	597
LLDPE	170 to 280	220	13 to 45	25	0.6497	2720	0.1267	530
PA6	230 to 280	250	50 to 85	60	0.6568	2750	0.1248	523
PA66	270 to 310	285	30 to 95	70	0.6688	2800	0.1438	602
PA11	240 to 300	275	30 to 90	60	0.6783	2840	0.1458	611
PA12	250 to 300	270	30 to 90	60	0.6091	2550	0.1279	536
PBT	220 to 270	245	50 to 130	75	0.4884	2045	0.0830	348
PC	270 to 320	290	70 to 120	80	0.5135	2150	0.1078	452
PEEK	360 to 400	380	160 to 200	180	0.5016	2100	0.1003	420
PEEL	200 to 240	220	30 to 60	40	0.4634	1940	0.0834	349
PES	320 to 380	360	120 to 180	150	0.3822	1600	0.0803	336
PETG	210 to 270	250	13 to 30	20	0.4610	1930	0.1060	444
PETP	260 to 305	285	80 to 130	90	0.4896	2050	0.0955	400
PMMA	210 to 270	245	50 to 90	70	0.5243	2195	0.0917	384
POM	185 to 230	205	40 to 120	70	0.4920	2060	0.0664	278
PP	200 to 280	240	13 to 50	20	0.6991	2927	0.1538	644
PPE/PPO-M	260 to 300	280	60 to 110	70	0.4466	1870	0.0938	393
PPS	290 to 360	320	60 to 120	90	0.4419	1850	0.1016	426
PPS	290 to 360	320	135 to 150	140	0.4419	1850	0.0795	333
PSU	320 to 380	350	120 to 180	150	0.5290	2215	0.1058	443
SAN	200 to 270	240	40 to 80	60	0.5159	2160	0.0929	389
PPVC	160 to 210	185	15 to 60	25	0.3869	1620	0.0619	259
UPVC	160 to 210	180	15 to 60	30	0.4395	1840	0.0659	276

Note: The specific heat values used in the above table are for general purpose grades which give a very good estimate of the heat content to be removed. For accurate heat removal rates the specific heat value for the particular grade should be obtained from the raw material manufacturer.

flow rate, heating capacity and temperature control of the cooling medium for a competitive price.

Where the mould tool is required to be heated, then the heating capability of the mould temperature controller needs to be taken into account. Furthermore, in addition to attaining the required working temperature, the ability to sustain or maintain that temperature to within defined limits is also important. However, if the mould tool requires a cooling medium temperature of 12 to 20°C a different approach is required. Irrespective of the actual requirements, both features will be considered.

When deriving the actual requirements for the mould temperature controller various principles need to be considered. Firstly thermoplastics materials, whether filled or unfilled, have optimum processing (melt temperature) and mould temperature values. In the case of mould temperature, this value is often a background value with the surface temperature of the cavity and core somewhat different. Maintenance of this temperature value is extremely important and critically influential in the outcome of cycle time and component quality.

Table 1 (previous page) highlights different thermoplastics materials with their corresponding melt and mould temperature values. Also included within the table is the specific heat value for each material for the range of mould to melt temperatures.

From a purely scientific viewpoint, there are changes in the specific heat value over the specified range. However, for mould temperature controller requirement calculations the average value is often used as the discrepancy is minimal. More importantly, the values given in Table 1 are for general purpose grades of each material type. It is recommended that processors contact their raw material supplier for specific heat values relating to particular grades.

To correctly specify a mould temperature controller for a particular application, five main factors need to be considered:

- The thermoplastics material being processed
- The size/dimensions or preferably weight of the mould tool
- The required pre-heat time to achieve the correct working temperature
- The expected cycle time for the production cell
- The output in litres/min of the selected cooling medium in association with the recommended pumping pressure.

Mould temperature controllers are often purchased to cater for a range of materials and mould tools rather than for a specific application, hence it is not always considered important to review such requirements. But by creating a simple Excel spread sheet, comparable requirements for each process can be readily reviewed and any performance deficiencies of the mould temperature controller can be quickly identified prior to encountering actual production issues.

The performance requirement of the mould temperature controller is broken down into three sections: Required heating power; Required cooling capacity; Required pumping capacity.

Required heating power

The required heating power to achieve the working temperature in a pre-determined time period for a mould tool is based upon its overall dimensions, density and the temperature required. When making volume calculations, it is not necessary to take into account free spaces such as the ejector box, overlap of the back plates, etc. All dimensions need to be calculated in metres.

The density value of the mould tool steel (in kg/m^{3}) differs according to the type of steel used. For example, H13 type steel (DIN 1.2344/1.2343), EN30B (DIN 1.2767) or a high chromium content (stainless) steel AISI 420 (DIN 1.2083).

The heating requirements to raise the mould tool from its storage to working temperature is calculated, for example 20°C to 70°C for PA66 (processing conditions from Table 1). To compensate for the inherent heat losses that occur from the cooling pipes, into the moulding machine platens and the connecting components, a safety factor of 1.3 is applied to the calculated value.

Required cooling capacity

Once the working temperature has been reached and production begun, the additional heat energy consumed in each cycle by the mould tool requires a further calculation to ensure the performance of the mould temperature controller is appropriate. The main components for this calculation are:

- The shot weight in grams
- Cycle time of moulding process in seconds
- Specific heat value of thermoplastics material at melt in kCal/kg/°C
- The reduction in temperature (ΔT) the plastics material undergoes to enable the resultant moulding to be effectively ejected from the mould tool (i.e. the ΔT from melt to mould tool temperature)

Required pumping capacity

Once the cooling capability requirement has been determined, the mould temperature controller pumping capacity needs to be considered. This is done by converting the calculated cooling capability during production into an equivalent cooling medium flow rate. The data required to carry out this function is as follows:

- Type of cooling medium being used (i.e water or oil)
- The temperature difference across the mould tool in terms of inlet to outlet temperatures of the cooling medium
- The density value of the cooling medium at the operating temperature
- The specific heat value of the cooling medium at the operating temperature.

This discussion will be continued in the next Moulding Masterclass instalment in the June edition of Injection World. If you wish to be sure you don't miss the next edition you can subscribe for free **here**.

About the author

John Goff is managing director of G&A Moulding Technology. This is the 20th instalment in the Moulding Masterclass series of articles. You can read the most recent instalments **here**, **here** and **here**.