Effective injection moulding requires an understanding of which variables control the process and which are consequential to it. Moulding expert **John Goff** explains this vital distinction and its role in maintaining part quality

Systematic process control should not stop at start-up

There is a very well known – and very truthful – saying in the injection moulding industry that it is easy to produce scrap quickly. Over the past few instalments in this series we have discussed how careful process setting procedures can avoid production of scrap parts. Achieving the most effective and economical component production requires meeting two particular criteria – quality and productivity.

As we all know, our goal is to produce injection moulded parts at the right level of quality in the most economical way. Naturally all stages of the moulding process must satisfy both criteria, but the emphasis for each stage may be different. For example, once good melt homogeneity is achieved the level of quality of the moulding is wholly attributable to the manner in which the mould cavity is filled with molten material, then how it is compacted and finally cooled. As a consequence, greater attention to part quality is given when selecting the process parameters for each of these stages.

Component removal and collection of mouldings can also affect part quality. However, emphasis is typically placed on how fast this stage of the process can be carried out.

It is, therefore, vitally important that a systematic procedure is undertaken that applies the correct focus for each stage. Without such a systematic approach, the controllable variables mentioned can be arbitrarily selected by the moulding technician, resulting in product quality changes within a production run or from run-to-run.

Furthermore, due to the interaction between particular process variables, changes made in a non-organised or indiscriminate manner can give rise to confusion by providing contradictory evidence as to which change in process parameter settings solved the issue. This is particularly so when several different process parameters are changed at once.

Process variables can be defined as controllable or consequential. Controllable variables are described as those that dictate the base line of component manufacture and productivity, while consequential process variables are those upon which the overall stability and robustness of a moulding process is assessed. Particular consequential variables can be attributed to each of the six main steps (see Table 1), with the added advantage of being presented in tabular form from the data collected each cycle by the computerised control within the injection moulding machine. These values are clearly displayed, allowing comparison with previous cycles, and highlight the deviation (range) between the values as well as the average value for a pre-selected number of consecutive cycles.

Consider the following example. A decrease in the mould surface temperature resulted in a shorter gate seal (freeze off) time causing a non-uniform surface finish, slight sinking and/or dimensional issues due to ineffective holding pressure application. The wrong response would be to increase the holding pressure to pack out the moulding as such an increase then uses more material, resulting in increased volume to achieve the same part dimensions/surface finish as well as greater inherent stress in the moulding.

In this example, changing the holding pressure masks the true cause of the defect, which is the decrease in the mould surface temperature. If the temperature of the part had been measured as per the initial process optimisation exercise, the decrease in temperature would have been noted and would have resulted in the correct investigation and conclusion.

Alternatively, an increase in the mould surface temperature due to either an issue with the mould temperature controller (MTC) or the cooling circuitry being wrongly connected can result in a variety of problems such as: longer gate seal time, easier cavity filling, over-packing of the cavity leading to ejector pin marks, surface finish or texture issues, burn marks and/or dimensional variation. Each of the above faults may be resolved using different approaches, while the main culprit (part temperature) is overlooked.

Consider a further example of a small reduction in the holding pressure applied when moulding semi-crystalline polymers, which results in changes in component shape and size and leads to alterations being made to cooling time, holding pressure time, mould tool and/or melt temperatures. Reference to the component weight created during the process optimisation exercise would have identified a loss in part volume/weight.

Adopting the optimised process settings as the base line for comparison with components from subsequent runs ensures consistent component manufacture at the correct quality standards. When mouldings deviate from the desired quality standard, objective assessment can be made using these reference settings and components previously derived.

This discussion will continue in next month's Moulding Masterclass instalment.

Table 1: Typical controllable and consequential process variables for the six main process steps

Process step	Controllable process variable	Consequential process variable
Conversion of solid granule to melt	Screw rotation speed Barrel temperature settings Feed/throat temperature Screw back pressure Decompression distance Utilised shot capacity	Screw recovery time
Manipulation of molten material to fill the mould cavity	Injection pressure Injection speed Screw stroke Mould tool temperature Changeover position	Injection pressure Injection time Changeover position Screw stop (end) position
Compaction of molten material within the mould cavity	Holding pressure Holding pressure time	Melt cushion
Movement of the mould halves and related speeds	Mould open/close distances Mould open/close speeds Clamp force application Mould too sensing speed/ pressure	Mould open/close time Side core actuation time
Solidification of the molten material in the mould cavity	Cooling time	Mould temperature Inlet/outlet coolant temperature
Removal of component from the mould and subsequent collection	Side core movement, speed and pressure Ejection stroke, speed and pressure Robotic movement and speed and placement position Gravity part collection Conveyor speed/dwell time	Ejector forward time Ejector return time Part extraction time Dwell time on conveyor Part weight Part temperature on ejection Part temperature on conveyor Part temperature in bulk container

About the author:

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