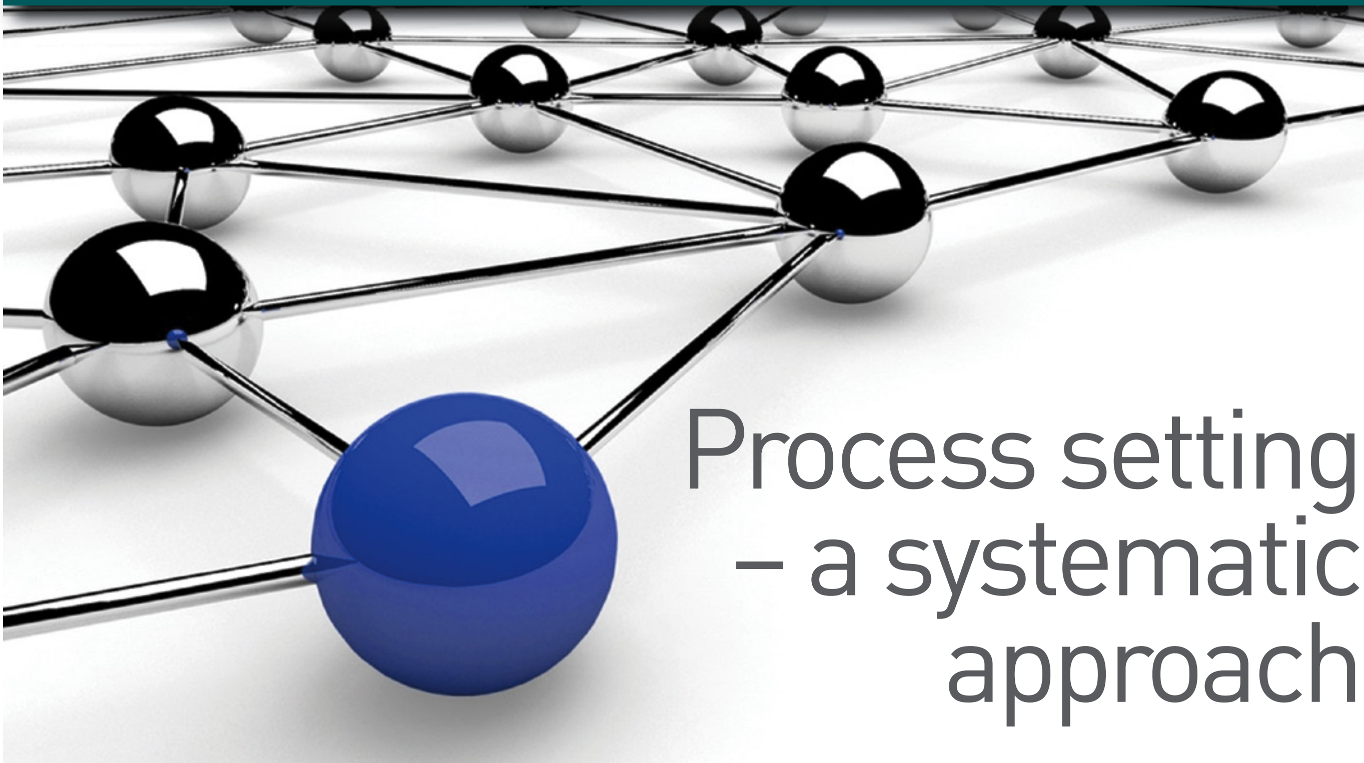
Previous articles in this series have looked at the influence of specific moulding parameters on part quality. In this instalment, **John Goff** discusses the systematic approach to determining a set of process conditions



Process setting – a systematic approach

Understanding how machine settings impact on part quality is only the first step in a systematic setting strategy

Readers of this Moulding Masterclass series of articles to date will have seen that the injection moulding process can be systematically broken down into a number of sections. When appropriately and technically addressed, each of these sections forms part of a "back bone" – an optimum set of processing conditions that results in effective and consistent component manufacture. For this reason, the injection moulding process should no longer be considered an "art" but classified as a "technology" that is based upon scientific and technological data and facts.

One of the big issues that is regularly confronted within the injection moulding industry is the manner in which a set of processing conditions is derived for a particular combination of mould tool, moulding machine and material, and whether such a set of conditions can sustain the relevant and required moulding quality standards and dimensional control throughout the production run and on a long term basis.

By adopting a systematic approach, the moulding parameter set created for a particular moulding process will provide the processor with a set of process conditions that ensure component manufacture takes place with the minimal amount of variation in product quality. Such a set of conditions is often termed as a "free and easy process" that is suitably stable and robust to continue to produce components that are compliant with the necessary quality standards and which prevents large numbers of defective components being produced. This approach is regularly employed for zero defect manufacture.

More importantly, the set of moulding conditions selected prevents defects occurring through raw material batch variability as a result of changes in MFR values, the use and percentage addition of different pigments and dye stuffs, the addition of regrind material, the variation in the control of virgin to regrind ratio, poor material handling procedures and other factors.

The systematic approach to obtaining this optimal set of process conditions involves the use of a stepwise procedure where each of the six important steps we have covered in previous articles are practically interrogated. The six main steps are:

- The conversion of the raw material from solid to liquid;
- The manipulation of the molten material to fill the relevant mould cavity or cavities to the required fullness;

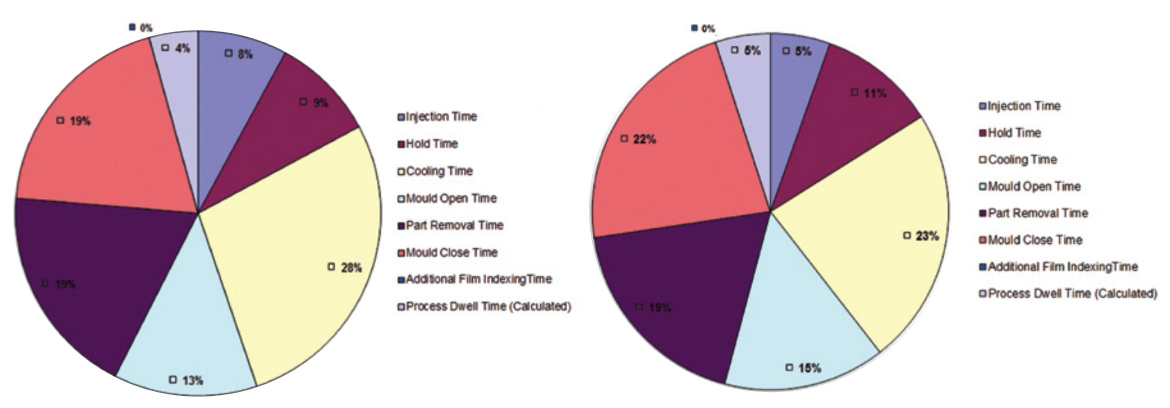


Figure 1a (left) and 1b: Simple pie charts can help identify areas of cycle time reduction

Source: G&A Moulding Technology

- The compaction of the molten material within the cavity to cater for the volume reduction during solidification;
- The overall movement of the mould tool halves and their related speeds;
- Further solidification of the material in the cavity or cavites to ensure suitable extraction/removal takes place without any shape change to the resultant moulding;
- The extraction/removal of the component from the cavity/core set(s) and its subsequent collection.

The conclusion of such activities results in the production of mouldings at an overall cycle time. Due to the manner in which the procedure is structured, other process variables such as pressure, volume, speed and temperature are selected and recorded for reference. The cycle time derived for the free and easy process becomes the base line against which an estimated and/or calculated cycle time is compared. Within the derived cycle time are incremental values applicable to the categories given above. Such a breakdown (*shown in Table 1 overleaf*) enables the processor to identify where certain time deficiencies are apparent when needing to achieve a required cycle time for profitability.

In addition to Table 1, the use of a simple pie chart (*Figures 1a and 1b*) provides the processor with further good information to identify areas in which particular time savings can be considered. For example, attempting to reduce the injection time (in terms of percentage reduction) below its optimum value can greatly affect not only the process consistency but also the quality and structural integrity of the moulded component. A similar percentage increment reduction to the cooling time (larger portion of the cycle) is far more readily achievable, without having a detrimental effect on the resultant moulding, by improving the rate of heat transfer/heat energy removal from the moulded component onto the adjacent cavity/core surfaces and the bolster plates into the cooling channel. Alternatively, the speed and manner in which the moulding is removed from the mould tool and collected for further use can also affect the percentage increment reduction.

Within Table 1, the actual response time for the moulding machine is also calculated. This response time is that where the machine control system electronically communicates with the actuators and mode of control functions within the machine, such as the time increment from end of holding pressure time to start of cooling; end of cooling time to mould open; and start of injection upon clamping force application.

These functions are listed for machines operating in a sequential mode, where one activity has to be completed before another can commence. For moulding machines which are capable of operating with parallel functions, then the dwell time is greatly minimised or even reduced to zero. This response time value can vary from machine to machine, even if identical in build and make. For this reason, when purchasing a moulding machine some processors will specify that the dwell times are tuned to particular values prior to delivery.

The listing and pictorial representation of such time values allows objective technical judgements to be made. In particular, mouldings produced with such time reductions can be objectively assessed against those produced from the previously-derived base line free and easy conditions for overall process consistency, part quality (including dimensional requirements) and structural integrity.

As stated in the introductory article of this series, the types of process parameters involved in achieving the optimised moulding process fall into two distinct categories: controllable and consequential. What can be seen from the individual articles is the greater influence and presence of the controllable variable, as its actual value directly correlates with a particular attribute of the moulded component, for example visual sinks, extent of inherent shrinkage, temperature of moulding upon ejection, flatness of moulding and surface finish. Typically such controllable variables can be assigned to each of the six steps listed earlier:

1. Conversion of solid granule to liquid melt – Melt plasticisation:

- Screw rotation speed
- Barrel temperature settings
- Feed/throat temperature
- Material intake temperature
- Screw back pressure
- Decompression distance
- Shot capacity utilised for component(s) manufacture (actual screw stroke)

2 The manipulation of the molten material to fill the relevant mould cavity or cavities to the required fullness:

- Injection pressure
- Injection speed
- Screw stroke
- Mould tool set temperatures
- Changeover position

3 The compaction of the molten material within the cavity to cater for the volume reduction during solidification:

- Holding pressure
- Holding pressure time

4 The overall movement of the mould tool halves and their related speeds:

- Mould open and close distances
- Mould open and close speed
- Clamping force application
- Mould tool sensing speeds/pressures

5 Further solidification of the material in the cavity or cavites to ensure suitable extraction/removal takes place without any shape change to the resultant moulding:

- Cooling time – mould temperature controller set temperatures and coolant flow rates

6 The extraction/removal of the component from the cavity/core set(s) and its subsequent collection:

- Side core movements, speeds and pressures
- Ejection strokes, speeds and pressure
- Robotic movements and product take out speeds and placement of mouldings
- Collection of mouldings via gravity
- Conveyor speeds and dwell time on conveyor

This discussion will be continued in the next instalment in the Moulding Masterclass series.

	Original	*Optimised*
Injection Time	0.86	*0.51*
Hold Time	1.00	*1.00*
Cooling Time	3.00	*2.20*
Mould Open Time	1.38	*1.38*
Part Removal Time	2.04	*1.74*
Mould Close Time	2.10	*2.10*
Additional Film IndexingTime	0.00	*0.00*
Process Dwell Time (Calculated)	*0.47*	*0.47*
Total Cycle Time	10.85	**9.40**
Saving (%)		**13%**

	Original	*Optimised*
Plasticising time	1.80	**1.20**

Weight Variation of Existing Process = 0.391%

Weight Variation of Optimised Process = 0.0882%

Table 1: The key elements of a moulding cycle before and after optimisation

About the author:

John Goff is a chartered engineer (CEng), a Fellow of the Institute of Materials, Mining and Metallurgy (FIMMM), and managing director of injection moulding process consultancy and moulding process optimisation software developer G&A Moulding Technology (www.gandamoulding.co.uk). This is the 24th instalment in his Moulding Masterclass series of injection moulding process optimisation articles. You can read the most recent instalments **here**, **here**, and **here**.

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