Once a stable moulding process is achieved, continuous process monitoring techniques will ensure optimum performance is maintained throughout the production run. **John Goff** explains how

Real time process monitoring

In the **previous edition**, the simple 32-shot analytical tool developed by statistician Frank Price was explained. It was said that a stable moulding process, where the percentage variation measured by the Price principle is 0.4% or less, would be classed as "free and easy" – meaning that the process has a certain level of inherent robustness to counteract external influences that could cause the moulded product to become non-compliant. The degree of resilience is dependent upon the level or severity of variance encountered.

For this reason it is common for data generated from the moulding process to be continually monitored so that trends - minor and/or step changes - can be readily identified, giving sound technical evidence for the processor to make effective process changes. Real time monitoring of selected process variables provides the individual moulder with objective and factual information regarding the level of performance of the moulding process throughout a production run.

Moulding companies that do not enjoy the luxury of having a real time monitoring facility can use the moulding machine instead. The on-board process monitoring facility will undertake cyclic duties by comparing the actual values derived to those set and subsequently record the offset. This offset is then compared to the upper and lower limits selected for the set value and, if found to be in excess, is then recorded as a deviation.

The number of deviations encountered for a particular number of moulding cycles, for example 1000, 2000 or 5000, is often governed by the overall AQL for both the component and quality system employed. A typical process monitoring page is shown in Figure 1, where the tolerance band specified for each of the process parameters would be selected as a result of the information achieved from either a Process Window Study or Design of Experimentation (DoE) exercise.

The main difference between the machine-based system and the external monitoring package is the manner in which the data is displayed. However, whether it is the off-line or machine-based version, the selection of such process parameters and extent of permitted variability is critical to ensure the overall stability of the moulding process is effectively assessed and correlates with the quality requirements of moulding.

The tolerance band provides invaluable information in addition to process stability assessment, as it offers good technical guidance if altering the process conditions. Upon such a condition change, if the resultant monitored value falls between the upper and lower limits then the moulded component will be compliant to the quality standard. Alternatively, the moulder has the knowledge that when such boundaries are breached, particular quality attributes of the moulding are affected causing non-conformal mouldings to be produced.

Unfortunately, within many moulding companies such monitoring capabilities are not used for a number of reasons:

- Too great a variability of the moulding process prevents sensible boundary values being selected or evaluated;
- Too wide a boundary limit (tolerance) is applied, so

Figure 1: Data from typical process monitoring page. The tolerance band for each process parameter would be selected from a PWC or DoE exercise.

Tool – deviation ■ [1000] 1000 Reset deviation □	Actual	Lower	Upper	Allowable deviation (%)	Actual deviation LL	Actual deviation UL	Output
Cycle time [s]	23.55	23.40	23.79	2 ■	0	0	
Inject time [s]	0.86	0.84	0.88	1 ■	0	0	
Dosing time [s]	0.44	0.40	0.46	2 ■	0	0	1
Screw stop [mm]	29.11	28.9	29.2	3 ■	0	0	1
Melt cushion [mm]	9.9	9.8	10.0	5 ■	0	0	
Barrel zone 3 [°C]	295	290	300	1 □	0	0	
Cav pr 1 –max	0	0	0	0 □	0	0	
Cav pr 1 – integral	0	0	0	0 □	0	0	
p-inj - max	763	755	770	3 ■	0	0	
p-inj –integral	90	85	95	3 ■	0	0	

providing an ineffective control of the process and typically resulting in non-compliant mouldings being undetected during the production run;

- Lack of awareness that a monitoring facility exists within the injection moulding machine;
- Inadequate understanding of how to effectively use the available monitoring facility.

For those moulding companies that are manufacturing components in accordance with strict guidelines imposed by regulatory bodies, then derivation of the upper and lower values for particular process variables becomes part of their moulding protocol. Furthermore, such procedures may stipulate that only designated process variables can be altered within the specified range and that the remainder are to be untouched.

To derive such boundary values a range of predictive techniques can be used, the most popular being Design of Experimentation (DoE). DoE principles are employed to ascertain the extent of variability that may inherently occur through process condition changes and to identify those variables that are more pertinent. Opinions are somewhat divided regarding the use of certain DoE packages and, for this reason, a universally accepted approach is not evident within the moulding industry.

Most moulders, therefore, employ their own approach and analysis package. However, when attempting to identify the extent of variability each process parameter induces it is important to ensure that the analysis does not include too much data. For example, the inclusion of the entire range of process variables used to produce the moulding as well as other influences such as raw material batch changes, different colours, different percentages of moisture within the material, different types of drying equipment, the use of gravimetric or volumetric additive addition or use of reground material.

Such an extensive range of data inclusion is too exhaustive for the analysis package to effectively assess and analyse, leading to confusion and contradiction rather than clarity. More importantly, not only is the outcome inconclusive but the time utilised to undertake such experimentation is wasted.

G&A Moulding Technology advises that when a moulding process has been suitably optimised and its stability verified using the Price 32-shot technique, the next step is to create a simple framework upon which critical process variables are increased and decreased around the optimised value. Such critical process variables will often include holding pressure, holding pressure time, cooling time, mould temperature, melt temperature, etc.

The actual selection of process variables used is dependent upon either the nature of the polymeric material being processed (semi-crystalline or amorphous) or the quality attributes that the moulding component is expected to meet in accordance with the physical dimensions. Therefore, the high and low boundary values used for a Window Study are determined during the process optimisation exercise. Furthermore, for each run (maximum usually nine runs) the effect of process consistency can be measured using the Price 32-shot technique.

This discussion will be continued.

About the author:

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This is the 26th instalment in his Moulding Masterclass series of injection moulding process optimisation articles and is the second part in a discussion on the understanding and effective use of measured process variables. You can read the most recent instalments in this series **here**, **here** and **here**.