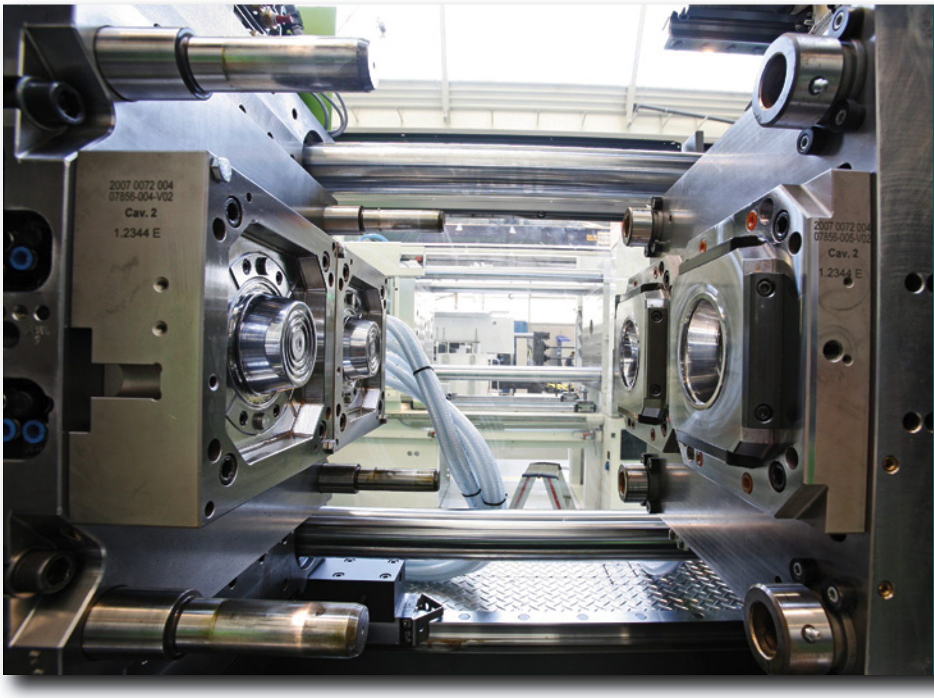

PHOTO: ENGEL/ZAO

Moulding expert **John Goff** continues his discussion of moulding machine clamping force selection in the latest instalment in his Moulding Masterclass series

Clamping down on variation

The previous instalment in this series looked at how incorrect selection of clamp force could impact on part quality. In this instalment, we will discuss the different factors that can affect clamping force and opening force during the moulding process and explore what can be done to minimise the induced process variation.

Clamping force will be affected by certain moulding process variables in association with the quality of mould tool manufacture and attributes such as the geometry of the runner and gate employed and/or the performance of any hot runner system installed.

Opening forces are, in turn, affected by the pressure value created within a mould cavity. The pressure value and consistency from cycle-to-cycle is influenced by the viscosity of the molten plastic and the speed at which it fills the impression. For this reason, it is essential to achieve a homogeneous melt and select an appropriate speed of fill. A homogenous melt results from adopting correct principles to ensure effective conversion of the solid granules into the molten liquid within the screw and barrel assembly. Speed of fill should be sufficiently fast to avoid viscosity changes through material batch changes or colour changes and to ensure minimal cavity pressure variation during each cycle.

Large variations in melt viscosity will induce different opening forces from cycle-to-cycle due to changes in cavity pressure, often leading to the clamping force value being set higher than necessary. This, in turn, results in dimensional and weight changes to the moulded component. Such changes may go unnoticed in single-cavity tooling but can be very noticeable with multi-impression mould tools, where the greater number of impressions results in a reduction in the latitude of process parameter selection. This reduction in latitude makes the process less robust, often described as the process "being on a knife edge".

More importantly, although all cavity and core sizes in the mould tool are measured as the same, the size differential across a critical dimension of a set of mouldings (shot) can be such that the variation may take up a large proportion of the applied tolerance, causing Cpk issues. For this reason, correct melt plasticisation is critical for the manufacture of components at fast cycle times using high cavitation mould tools. Although clamping force is one of the last elements to be considered when optimising the moulding process, it is greatly affected by how well the plastic material is converted into a molten liquid.

Clamping force optimisation can be undertaken by monitoring the change in shot volume when selecting different values. Upon each clamping force value selection, either the collective weight of all mould impressions or the weight of a designated impression or set of impressions is measured to a resolution that

Following a structured clamp force optimisation plan will ensure maximum process stabilty and is particularly beneficial in multi-cavity mould tools

Clamp Force		Part Weight				Part Quality Comments	Percentage Change
%	t/kN	Shot 1	Shot 2	Shot 3	Average		
	600	11.8679	11.8809	11.8628	11.8705		
	500	11.8741	11.8736	11.8732	11.8736		0.03%
	450	11.8730	11.8736	11.8735	11.8734		0.01%
	400	11.8729	11.8731	11.8735	11.8732		0.01%
	300	11.8833	11.8835	11.8803	11.8824		0.07%
	200	11.8934	11.8846	11.8909	11.8896		0.06%
	100	11.8944	11.9007	11.8960	11.8970		0.06%

Optimised Clamping Force	450	Insert optimised value
Clamping Force per Cavity	225.0	<< Select Units

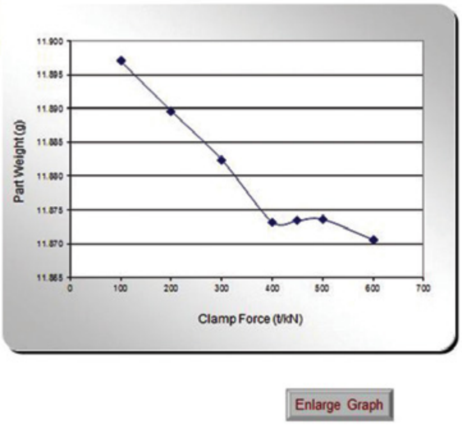

Figure 1 (on left above): Table showing example data collected as part of a clamp force optimisation protocol
Figure 2 (on right): Graphical analysis of clamp force and part weigh identifies the optimum value

suits the shot weight under consideration.

Selection of the measurement resolution is very important, when undertaking this optimisation exercise, to ensure that any minor changes in the component weight are detected. As a guide, for components weighing up to 1kg a measurement resolution of 0.1g is necessary, whereas above 1kg a typical resolution would be 0.5g-1.0g. For components of less than 20g, a resolution of 0.0001g will be required.

In addition to weight monitoring, both the melt cushion and injection pressure values should be recorded for reference purposes. Figure 1 highlights a typical set of results from this simple and effective systematic procedure.

In summary, the procedure for determining the correct clamping force is as follows:

- Set the moulding machine at maximum clamping force and weigh parts produced;
- Reduce the clamping force in increments of 5-10 tonnes or 50-100 kN, weighing parts at each incremental change (for much larger machines the incremental change should be 100-200 tonnes or 1,000 to 2,000kn);
- Continue to reduce the clamping force and weigh the parts produced using same force reduction intervals until there is a significant change in weight but insufficient reduction to induce flash;
- Plot the clamping force against weight value at all times to produce a curve such as shown in Figure 2.

Within the determined clamping force range, there is often a set of values that will create consistent component manufacture and allow entrapped air within the impression to escape to marginally increase the weight of the moulding. In other words, the mould impression will be filled to its full extremities without detrimentally affecting the visual quality of the mouldings.

Above this range, further reduction of the clamping force value increases the component weight to a point which induces variability from cycle-to-cycle. It will eventually cause flash on the component as the gap between the mating faces of the mould tool becomes too great. Low viscosity materials are more critical than high viscosity materials when optimising clamping force. For the same size of gap created between the mould halves, the low viscosity materials will penetrate further to give minute traces of flash.

By undertaking this simple, systematic protocol when trialling and setting mould tools, the most effective and optimum clamping force for a mould tool/material combination can be effectively determined. This improved understanding of the actual clamping force required can result in component cost reduction and increased flexibility in planning production schedules. For instance, it may reveal that a smaller moulding machine can be used.

Transfer of a mould tool from one machine to another will be discussed in a later article as size and geometry of the mould tool are not the only factors to be considered; screw size and other factors also need to be taken into account.

About the author:

John Goff is a chartered engineer, a Fellow of IoM3 (Institute of Materials, Mining and Metallurgy) and managing director of injection moulding process consultancy 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**.

If you want to make sure you don't miss the next instalment in the Moulding Masterclass series, you can subscribe to *Injection World* for free **here**.