John Goff explains how to use the relative viscosity–shear rate curve to determine the right injection time in the latest article in his series on process optimisation

The art of selecting the correct injection time

Achieving the correct injection time is relatively simple using the data generated by the injection moulding machine. Modern injection moulding machines can be programmed to measure and display the specific injection pressure. To determine the optimum injection time, both the specific injection pressure and injection time need to be recorded for each set of injection speed settings. Upon filling the mould cavities to 95-98% fullness at each selected injection speed, the corresponding injection pressure and time values are used to generate a viscosity–shear rate graph (Figure 1).

This graph provides the processor with an injection time window ranging from short mouldings to flashed or poor quality components. This means that values between these two extremities will suitably fill the mould cavities with the required volume for the required product quality. To achieve the best performance from a moulded component, as well as the most stable process, a position needs to be selected on the viscosity–shear rate curve. But what is the best time selection?

The main criterion for injection moulding is to use the most efficient and lowest injection time value for the material–mould–machine combination. This is based on the following elements: that the internal structure of the part is suitable for the end performance require-

Injection time takes precedence over injection speed when optimising the filling of a mould

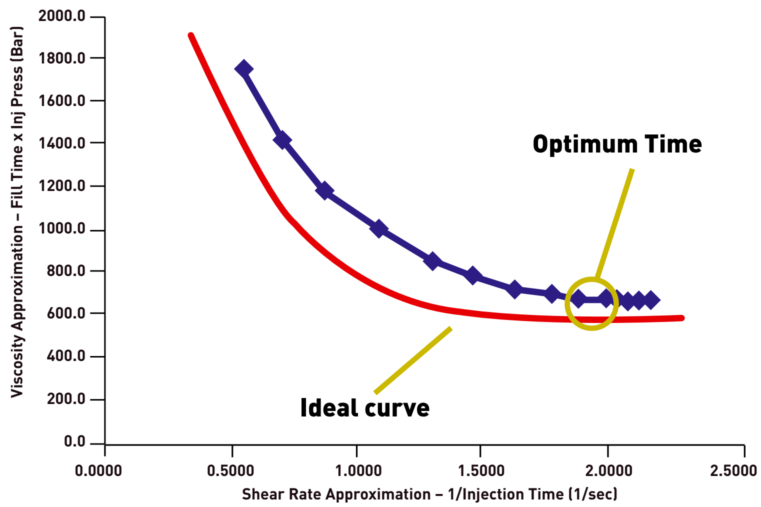

FIGURE 1: VISCOSITY–SHEAR RATE GRAPH SHOWING AN INJECTION TIME WINDOW RANGING FROM SHORT MOULDINGS TO A POOR QUALITY COMPONENT

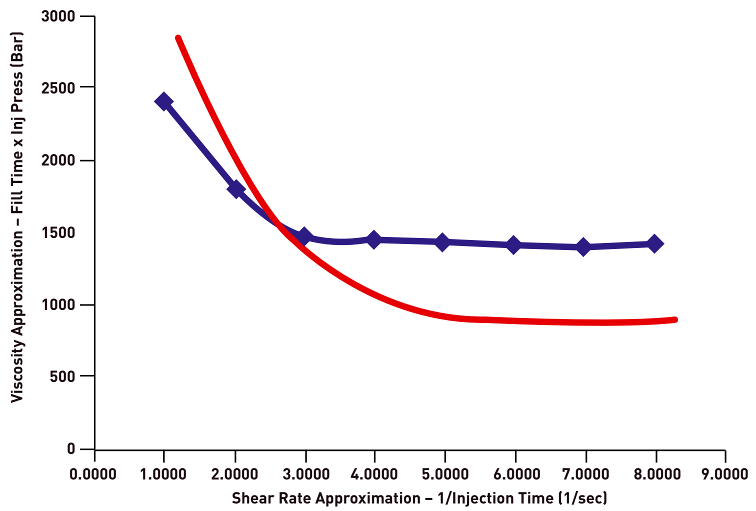

FIGURE 2: AN IDEAL VISCOSITY–SHEAR RATE CURVE

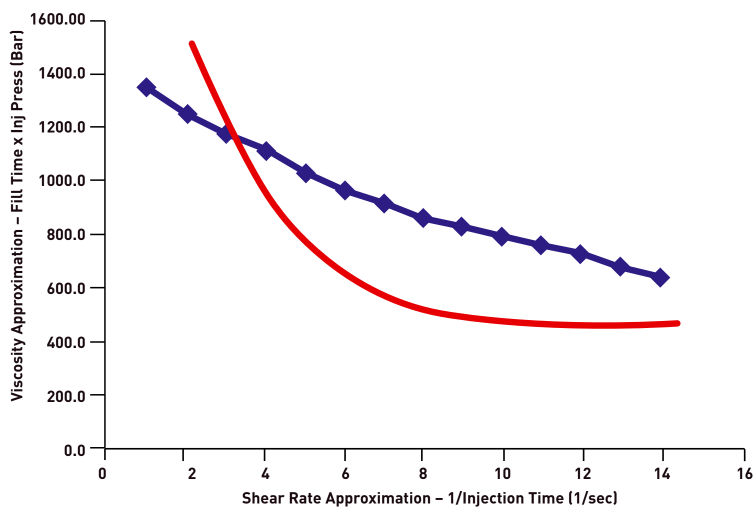

FIGURE 3: REDUCED INJECTION TIME VALUE AND CORRESPONDING DECREASE IN MELT VISCOSITY RESULTS IN AN OVER-SHEARED MATERIAL

ments, surface finish requirements, shot-to-shot consistency, and the ability of the process to cope with inherent material batch-to-batch variations, including colour variations.

Interpolation of the injection time curve shows that when using longer injection time values the melt viscosity changes considerably. This means that an inherent viscosity variation encountered within the polymer melt will be reflected in product quality and dimensional variability.

Aid to troubleshooting

From an optimum moulding performance viewpoint, the creation of the relative viscosity–shear rate curve can also act as a troubleshooting aid. Review of various injection time curves will show particular issues with the attributes of the mould tool or injection moulding machine.

Figure 2 depicts an injection time curve where the maximum available injection pressure on the moulding machine was reached and the selection of an injection speed value from 80 mm/s to 102 mm/s (maximum available on the machine) made no difference to the time value, which then caused the process to be converted from a speed control to pressure control mode (pressure dictating speed). Issues like this induce poor part quality, and too long an injection time gives poor surface finish.

Figure 2 also shows an ideal curve that allows the melt volume to be injected into the mould tool with control and capability and demonstrates that the size (area) of the gate is optimal for this material and component.

The curve in Figure 3 shows the reverse is being applied. It indicates that after a reduction in the injection time value, the corresponding melt viscosity decreases significantly with no real plateau to result in an over-sheared material.

Profiles like this highlight that a restriction is present in the hot or cold runner feed system or that the gate aperture is too small. The creation of this relative viscosity–shear rate curve can be undertaken when conducting a performance enhancement exercise on an existing component/process or on a newly manufactured mould tool. At G&A Moulding Technology we utilise this technique as part of our setting protocol. Furthermore, the efficiency and responding performance of the moulding machine can be assessed.

Conducting a process trial

The process trials used to determine the optimum injection time are performed "under load." That is, the screw and barrel assembly is full of molten and solid material, and the molten material is forced through the nozzle, feed system and gate of the mould tool before entering the impression. Therefore, the injection times recorded are dependent on the ability of the polymer melt to overcome the resistances it encounters during its passage through the mould tool.

A simple test to determine how the moulding machine hardware correlates with the control software system is to conduct an "air shot." This is the same exercise, but with the nozzle of the screw and barrel assembly not in contact with the sprue bushing of the mould tool. This means the molten material is injected from the screw and barrel assembly via the orifice of the nozzle and is subsequently allowed to solidify in the guarded area on the bed of the machine.

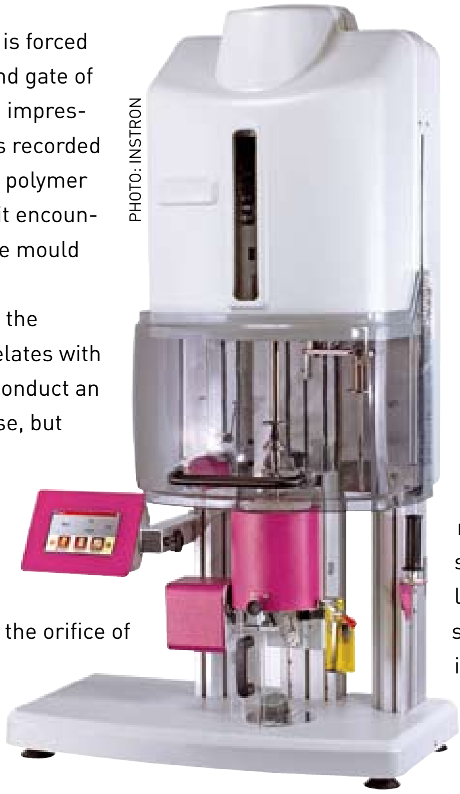

PHOTO: INSTRON

By refilling the screw and barrel assembly to the specified injection speed value, a further set of injection time and pressure values can be determined. The discrepancy between the two time values in "under load" and "air shot" experiments is often used to differentiate the capabilities of different types and models of moulding machine.

Important features regarding the rate of acceleration upon initial screw movement, the selected injection speed setting, and the speed of communication between the control system and the actuator to initiate screw movement are often assessed leading to performance evaluation of individual moulding machine makes and models. These assessments are undertaken for those machines that require calibrating as part of their planned maintenance schedule. Furthermore, they are valuable for fast cycling processes or those that necessitate rapid filling times for consistency of response and conciseness of melt volume delivery each cycle.

Why time takes precedence

Processors often ask why injection time takes precedence over injection speed. One of the more important process parameters when transferring a mould tool from one moulding machine to another is injection time because the recipient injection moulding machine may have, amongst other attributes, a different screw and barrel diameter or maximum screw stroke length. This means that for the original time value to be achieved on the new machine, a different injection speed may be necessary.

The following is an example of what can often happen. During the second day of running an eight impression mould tool in production, one of the impressions becomes defective due to a mould tool problem. For expediency and production requirements, the processor is requested to block-off the defective cavity. The production run recommences with the mould tool now producing seven mouldings each cycle. To achieve the status of seven impressions it is a natural reaction to reduce the screw stroke length to compensate for the loss in shot volume for one impression. In so doing the original injection time value used for eight impressions is now altered to a lower value. This is due to the original injection speed setting now being utilised over the new reduced screw stroke length, which results in a faster time value.

In certain circumstances this difference is not a problem. In fact, various production personnel will welcome this time reduction to offset the lower number of components being produced per hour, compared with the output when eight impressions were being produced. In many circumstances, however, the reduction in the injection time causes part quality issues for some or all of the other seven components, which were not present when producing eight mouldings. The lower injection time induces more shear to the polymer melt, which in turn often affects its viscosity and causes gassing, flashing, dimensional issues, surface splay and colour variation on the seven remaining mouldings. These occurrences are more prevalent the higher the number of impressions contained in the mould tool.

For optimal performance moulding, therefore, not only should the shot volume be adjusted, but also the injection speed to maintain the same time value for the manufacture of the reduced number of components.

To be continued.

Understanding the melt flow properties of a resin is important when optimising injection times

More information

This is the twelfth article in the Moulding Masterclass series, which discusses the fundamental issues that prevent optimal injection cycles. Recent articles can be accessed, here, here and here, respectively. John Goff is Managing Director of G&A Moulding Technology.

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