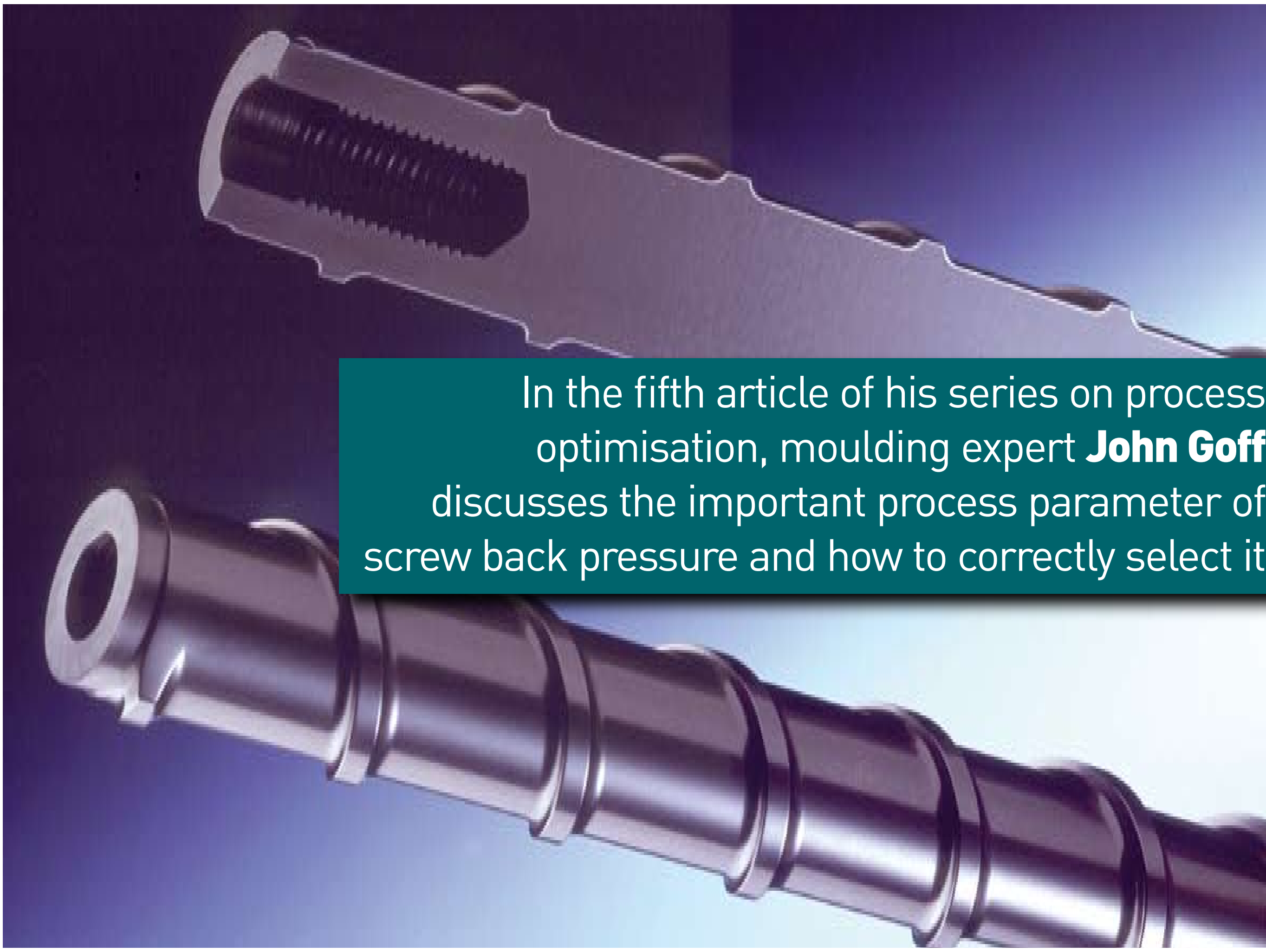

PHOTO: ENGEL

In the fifth article of his series on process optimisation, moulding expert **John Goff** discusses the important process parameter of screw back pressure and how to correctly select it

Determining optimum screw back pressures

Melt plasticization (plastification) relies on an effective input of heat energy. As stated in an earlier **article** in this series, the ratio of energy input is 70:30 in favour of frictional energy over conductive energy. In conjunction with the selected screw surface speed value for the material–mould–machine combination, the selected value for screw back pressure is instrumental in achieving the required energy input in association with shot volume consistency.

Screw back pressure is a controllable process parameter that is often mistakenly overlooked. It is the pressure generated at the front end of the screw as the screw is rotated. It causes the heat softened (plasticized) material to be forced along the metering section of the screw and through the non-return (check ring) valve assembly. Because of the build up of material, pressure is created and when it is of sufficient value it will force the rotating screw backwards towards its metering or dosing stroke position. Therefore, as the rotating screw moves backwards, material enters and increases in volume at the front of the rotating screw, and this filling continues until the screw reaches its selected stroke position.

The manner in which the screw rotates is paramount to ensuring that a consistent volume of material is injected into the mould tool each cycle. Selection of the correct resistance value applied to the back of the reciprocating screw needs to be effectively performed, either hydraulically from the oil contained behind the piston head within the injection cylinder, or by load cells used in conjunction with the servo motor.

Particularly with hydraulically actuated machines, a

It is critical to ensure that the correct resistance value is applied to the back of the reciprocating screw

restriction of the oil flow from the inlet part of the injection cylinder increases resistance pressure between the piston head and the cylinder chamber. The greater the restriction of oil flow, the higher the resistance pressure generated, the screw then takes longer to return to the selected dosing or metering stop position, and more shear (frictional energy) is applied.

With servo electric moulding machines, the screw back pressure value is determined by measuring the actual force on the screw by means of a load cell. The force is directly proportional to the actual pressure being applied. This concept is widely used for servo electric machine technology, however, with the range of machines now available other methods may be used. In any case, the pressure applied would be related to the force generated.

Because screw back pressure is an important process parameter, the value selected needs to be accurately optimised and the trend to use closed loop control to do this has become the norm. By tradition, screw back pressure is selected for various reasons, to

- displace volatiles (including air) from the inside the barrel
- uniformly disperse additives within the polymer melt
- achieve consistent plasticization of thermoplastic materials and thereby enable accurate shot weight control
- cater for change in effective or working length of screw during screw recovery.

The net result of any of the above four factors is the ability to contribute to obtaining an homogenous melt. The selection of the correct screw back pressure value in accordance with the correct screw surface speed produces a synergistic, considerably improved effect that results in an homogenous melt. Back pressure that is too high causes variations in the shot volume due to lack of accurate control of the overrun of the screw. The extent of overrun is influenced by the visco-elastic behaviour of the polymeric material being processed. Back pressure that is too low causes the screw to return to its dosing stop without properly mixing the material and hence results in a poorly plasticized material.

Selecting the right screw back pressure is critical to optimising product quality and minimising cycle times. This Engel e-cap machine will be running a 96-cavity closure mould with a cycle time of less than 3 seconds at K 2010

Set up example I: Calculation of specific screw back pressure

Area of piston: 176.74 cm^2
Area of screw: 12.57 cm^2
Maximum operating pressure: 160 bar hydraulic
Maximum available operating specific pressure:
$\frac{176.74}{12.57}$ x 160 = 2249.67 or 2250 bar

Set hydraulic pressure of 8 bar will be converted into
$\frac{8}{160}$ x 2260 = 112.5 bar specific

Screw back pressure will increase the temperature of the melt because of the additional shear (friction) being applied, therefore the higher the back pressure, the higher the temperature. Any significant rise in temperature has to be removed via the mould tool during the cooling segment of the moulding cycle. Therefore, the amount of screw back pressure used should be at an optimised value, one that is sufficient to achieve melt homogeneity, but not so excessive that it extends the cycle time.

If when adding masterbatch the result is inconsistent dispersion or the wrong shade or colour intensity, often the natural tendency is to increase the screw back pressure to achieve the desired results. Many times, however, the comment is made: "We are not as consistent with this masterbatch colour as we are with others we use". The increase in back pressure simply increases the inherent variability that is due to the visco-elastic behaviour of the raw material. For this reason, instead of increasing screw back pressure, which is merely a short term fix, other forms of dispersion need to be considered, that is, a filter nozzle or a review of the composition of the masterbatch.

Screw back pressure can be expressed in two ways:

- Hydraulic screw back pressure
- Specific screw back pressure.

The difference between the two, particularly with an hydraulically actuated machine, is related to the ratio of the area of the injection piston to that of the screw and the available operating pump pressure. Melt or specific screw back pressure is always higher than hydraulic screw back pressure usually by 10 to 15:1. Two set up examples illustrate this. In Set up example I, a set hydraulic screw back pressure of 8 bar, a screw diameter of 40 mm connected to the injection piston of

Set up example II: Calculation of specific screw back pressure in a second moulding machine

Area of piston: 122.73 cm^2

Area of screw: 12.57 cm^2

Maximum operating pressure: 160 bar hydraulic

Maximum available operating specific pressure:

$\frac{122.73}{12.57} \times 160 = 1562$ bar

Set hydraulic pressure of 8 bar will be converted into

$\frac{8}{160} \times 1562 = 78.1$ or 78 bar specific

150 mm in diameter, at a maximum operating pressure of 160 bar hydraulic, would be converted to 112.5 bar specific, giving a ratio of 14:1.

It is important to note that selecting an hydraulic screw back pressure for a setting value requires caution. This value cannot simply be transferred when mounting this mould tool into a different moulding machine because it cannot be assumed to be factually correct. As shown in Set up example II, if the new moulding machine is of a different make and has an operating pressure of 160 bar hydraulic for a similar screw diameter of 40 mm and an injection piston of 125 mm, then the set hydraulic pressure of 8 bar would convert to a melt or specific back pressure of 78 bar specific.

For this reason, specific screw back values should always be determined and referred to for setting sheet purposes. In general, screw back pressures of 40 to 180 bar specific are used, typically 50 to 120 bar. Values in excess of these require investigation into their necessity. Often the presence of too high a back pressure is reflected by the amount of temperature overshoot monitored by the heating zones along the barrel assembly. The excess temperature is solely the result of friction (adiabatic) heating derived from the screw.

More information

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

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