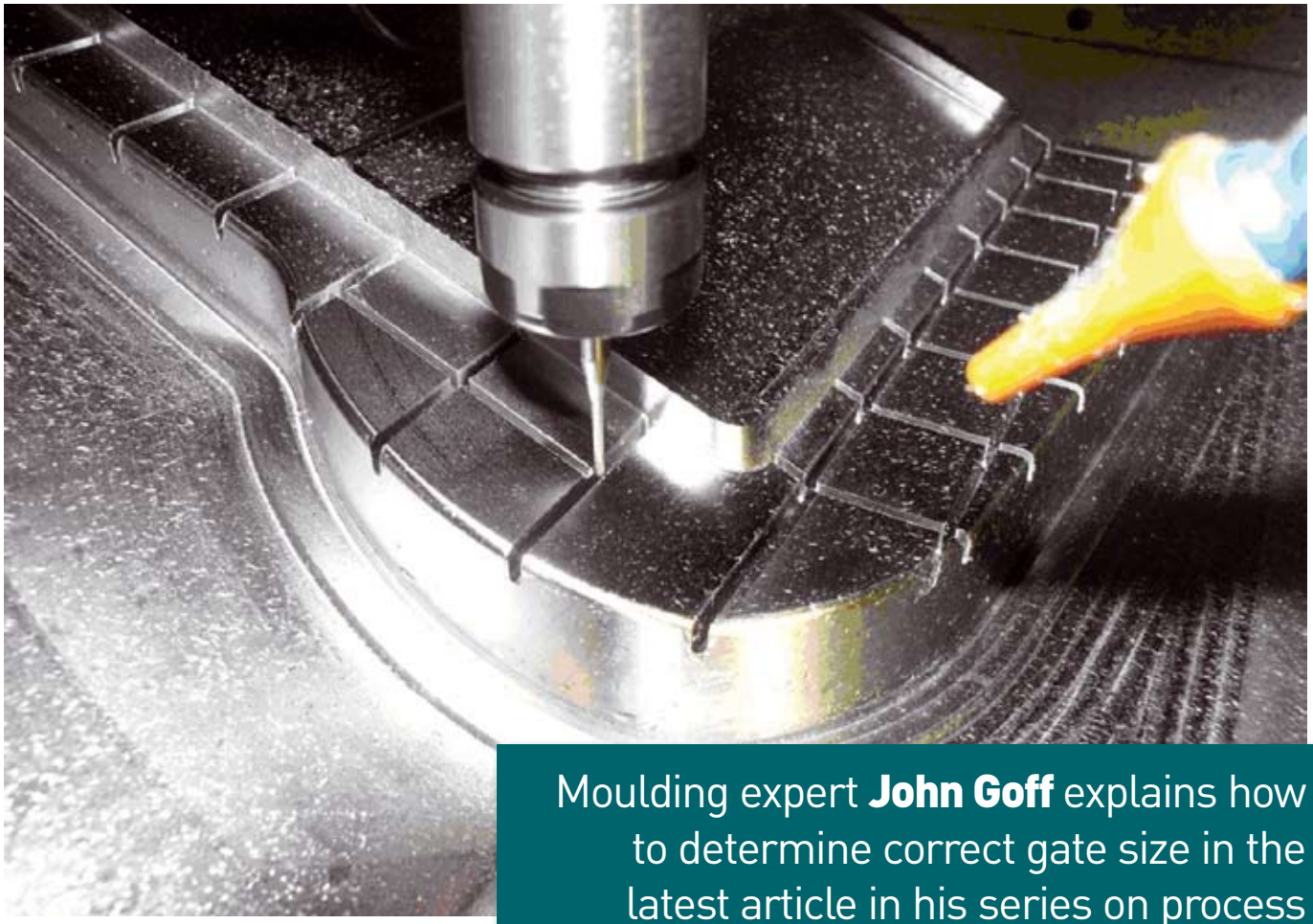


Moulding expert **John Goff** explains how to determine correct gate size in the latest article in his series on process optimisation and trouble shooting

The importance of gate size

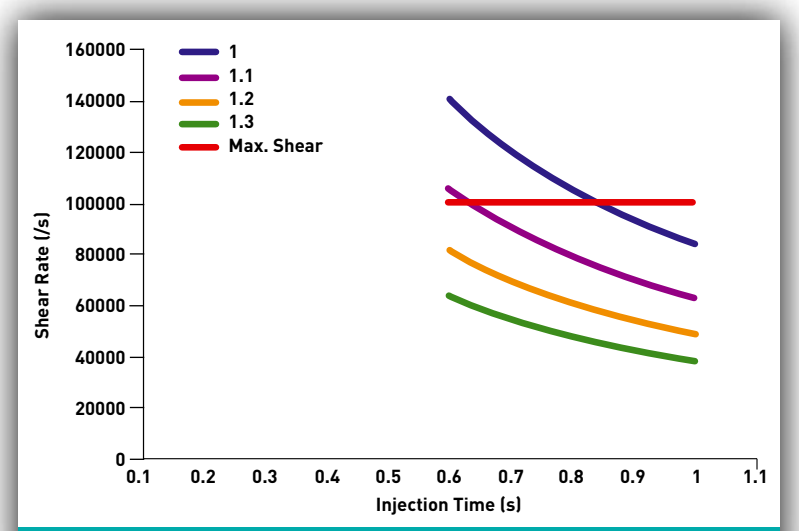
The previous **article** in this series described how to determine the most efficient injection time for a mould tool–moulding machine–material combination with the aid of the relative viscosity/shear rate graph. Once injection time is selected, it must be verified. This is to ensure that the feed system incorporated in the mould tool, and the gate in particular, has been optimally sized so that the thermoplastic material is not structurally damaged as it passes in its molten state through the gate's orifice and/or along the flow path within the impression.

Penalties of incorrect gate size

In the injection moulding industry the following is a very common occurrence. The gate is initially machined at a value that is too small on the basis that this allows the opportunity for it to be increased, if required, at a later point in mould tool validation. Unfortunately, in many cases, the moulding conditions ultimately selected are the result of a desire to overcome some of the defects caused by the inclusion of a small gate. These defects/issues with component quality include gate bloom; cracks appearing in the gate area some time after the moulding has been produced; high inherent stresses within the moulding resulting in premature failure whilst in service; gas entrapment within the moulding; porosity within the moulding (in particular in the region of the gate); excessive component shape change (deformation); the presence of sink marks, poor surface finish and lack of consistency of surface texture; poor optical properties and image projection issues; ovality within components; and the presence of voids in the components.

Thus, the overall situation is that a particular set of processing conditions has been manipulated to overcome issues of poor quality, which result in long

Cavity machining may be computer controlled but gate sizing is often left to trial and error, a decision that can compromise part quality, says John Goff (Image: Delcam)



GATE DIAMETER INJECTION CURVES

term process instability and varying product quality.

The initial decision to make a small gate is because it is much easier and more cost-effective to open the gate aperture rather than weld the existing gate to make it smaller, or to include an insert or replace the cavity/core.

Calculating correct gate size

This gate situation occurs too often to be overlooked. At G&A Moulding Technology we prioritise our efforts to ensure that the size of the gate of any component is suitably calculated. This takes into account the thermoplastic material and related set of process conditions for a newly manufactured, existing and/or refurbished mould tool. For these calculations, both the actual derived injection time and the corresponding component weight need to be ascertained. This weight value is then converted into a melt volume to determine the volumetric flow rate of the polymer melt as it passes through the gate and into the cavity. This rate value is expressed in cm^3/s.

A well established rheological equation for a circular orifice that is used to calculate the extent of interlayer friction (apparent shear rate) within the molten material as it passes through the gate and fills the cavity is:

$$\frac{4Q}{\pi R^3}$$

where Q is the volumetric filling rate and R is the radius of the circular orifice. Here is a typical example:

Derived injection time = 0.8 s
Diameter of circular gate = 1.0 mm
Weight of moulding = 6.32 g
Material being used = PP (PP homopolyer)

G&A's gate calculation method using its own gate calculator highlights the extent of shear (friction) being generated within the molten material for cylindrical and rectangular gates. The values the calculator generates relate to the respective shear rates for a range of gate sizes and given injection times. The shear rate values quoted by the raw material suppliers are extremely important because each type and grade of thermoplastic material should be suitably processed within the given recommended range.

Adherence to maximum shear rates

Shear rate values in excess of the recommended maximum will ultimately cause structural issues within the moulded component. Good moulding practice recommends that shear rate values are contained within those specified by the raw material manufacturer. Each type of thermoplastic material has its own range. For example, PP has a recommended maximum of 100,000 s^{-1} whereas for PC it is 40,000 s^{-1}.

Compliance with these values is imperative, particularly with certain types of thermoplastic material. For example, general purpose grades of ABS have a recommended maximum of up to 50,000 s^{-1}. For chrome plated grades the maximum is 30,000 s^{-1}

CIRCULAR GATE SIZE CALCULATION

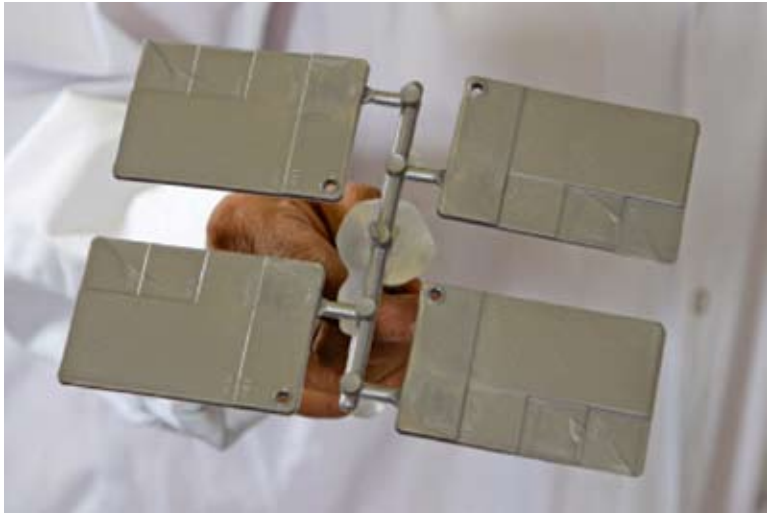
$$\text{Shear Rate} = \frac{4Q}{3.142xr^3}$$

Q ($cm^3/_8$) Shot Volume/Injection time
r (cm) = (Gate Diameter/2) /10

Melt Density = Material Density x 0.85

Maximum Material Shear Rate	100,000
Component Weight (g)	6.3200
Material Density (g/cc)	0.9
Melt Density (g/cc)	0.77
Shot Volume (cc)	8.26

Gate Diameter (mm)	Injection Time (s) 0.6	0.7	0.8	0.9	1
1	140232	120199	105174	93488	84139
1.1	105359	90307	79019	70239	63215
1.2	81153	69560	60865	54102	48692
1.3	63829	54711	47872	42553	38297
Max Shear	100,000	100,000	100,000	100,000	100,000



Appropriate gate sizing is science, not art

because the internal molecular structure and inherent stress levels need to be controlled; too high a shear rate will cause chrome plating issues such as micro cracks, porosity and/or poor surface finish.

Use of the G&A calculation method provides the product designer, mould tool manufacturer and the processor with suitable information to allow the gate aperture, type and geometry to be optimised before any components are moulded. It can also be used as a trouble shooting tool during mould tool validation to decipher whether the gate orifice and the relevant injection time are compatible.

The calculator (*see Table*) demonstrates that the values in red are too high and the acceptable figures are in green. From the example above, the calculated shear rate value for a 1-mm gate at the derived injection time of 0.8 s is 105,175 s^{-1}, which is above the recommended maximum for PP. By simply increasing the gate to 1.1 mm, the inherent shear rate reduces to 79,019 s^{-1}, which enables the material being processed to have the correct structural attributes. Furthermore, a process window from 0.7 s to 0.9 s could be applied.

More information

This is the thirteenth 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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