When is a moulding problem the fault of the screw tip and when is it not? **John Goff** provides the answers in his latest article on process optimisation

Improving screw tip performance

Screw tip technology is an important factor in component quality. Its inconsistent operation and/or malfunction are responsible for many problems encountered by moulders and prompt the statement, "how many more times do we have to remove the screw tip assembly to resolve this issue?"

Screw tips are designed to wear, which often leads to inconsistent product quality. Equally, though, it is often the selected processing conditions that give rise to problems that are blamed on the screw tip. Faults need to be identified before embarking on screw tip removal because this can be a lengthy process that is costly in production down time.

Solutions to surface splay marks

The moulding of optical, automotive, lens, bezel and fascia components using PC, PMMA, PEI and/or PSU often gives rise to splash or surface splay marks. These can be in form of single lines or a cluster of fine lines deemed unacceptable with today's demanding quality standards. Initially, their presence can be thought to be related to material that has not been fully dried or where poor plasticization has occurred. In fact, they are associated with the amount of air being drawn into the barrel assembly via the hopper, at the nozzle seal point with the sprue bushing, and/or the gap between the relaxed frozen layer and thermal hot tip in a static tip, hot runner mould tool.

In an attempt to resolve the problem, decompression stroke or speed is often reduced. The marks disappear, but short or incomplete mouldings are intermittently produced. These mouldings can also be accompanied by an erratic melt cushion value from cycle to cycle. Naturally, component weight variation also occurs.

The actual problem is related to the position of the sleeve within the screw tip assembly prior to closure. The sleeve has to travel an optimum distance to ensure that positive and consistent contact (seal) is made with the pressure back ring. Too small a distance does not allow for sufficient inertia to cause a positive seal on the forward movement of the screw during injection. A poor seal will provide a pathway for molten material to be forced backwards into the metering section of the Archimedean screw, causing shorts or underweight components. Conversely, too much distance allows an excessive amount of air to be drawn into the molten material, which results in a surface mark or blemish. Moulders often attempt to overcome this conundrum by

- lowering the barrel temperature settings of the end cap assembly so that a more viscous melt is produced;

The moulding of high quality optical parts, such as car headlamps, demands particular care to avoid splash or surface splay marks

PHOTO: BMW


PHOTO: GROCHE

this, in turn, allows the sleeve to be forced backwards onto the pressure back ring without excessive loss of material flowing backwards

- using a fast injection speed for the first 3–6 mm of screw movement in an effort to force the sleeve backwards onto the sealing face of the pressure ring
- selecting a slower decompression speed to try to more accurately control the position of the sleeve.

A better approach is to reduce the movement of the sleeve within the screw tip assembly so that the stroke can be maintained at a more effective length: sufficient to achieve shot weight consistency, but not enough to draw excessive air into the polymeric material. Careful attention needs to be paid to the amount of metal removed from the shoulder of the torpedo so that the lesser stroke does not create too small a gap between the mating faces of the sleeve and pressure back ring, which would result in excessive shear being applied to the melt as it passes between them. Attempting to force the melt through a restrictive gap will also induce more pressure in the front face of the sleeve, which will cause unnecessary wear and lead to a shorter working life for the screw tip assembly.

One noticeable change when reducing the gap is an increase in screw recovery time. Quite often this increase is incrementally small; however the increase must not interfere with the original cooling time, particularly if the moulding machine operates on a sequential mode. This means that the screw recovery time must be completed within the cooling time otherwise the mould tool will not open until the screw reaches its final screw stroke position, which increases cycle time.

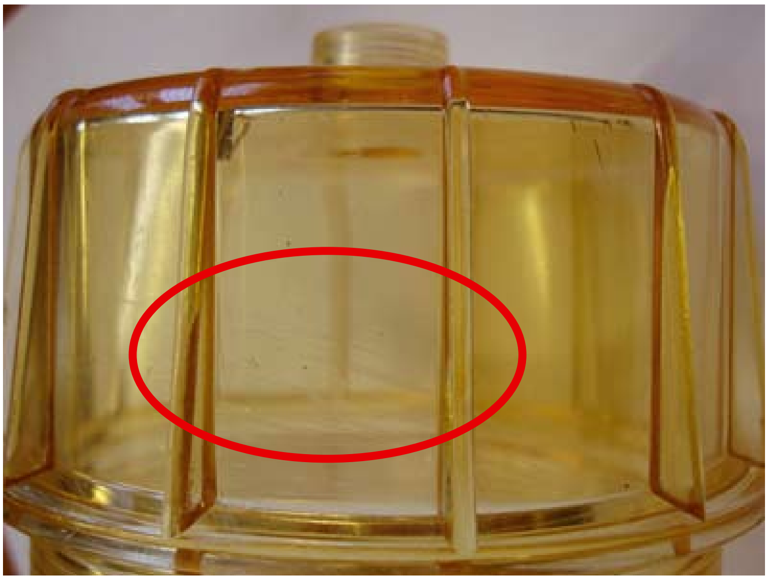
Importance of process parameters

Poor screw tip performance is often the reason given for varying part quality when the real cause is poor process parameter selection. Semi-crystalline materials such as acetals (POM), nylons (PAs), saturated polyesters (PBT), olefins (PP, PEHD, PELLD), PPS and liquid crystal polymers are more likely to exhibit this problem. An occasional short or incomplete moulding may spasmodically occur throughout a production run; PP is renowned for this, particularly when producing components in fast cycles. I have discussed these problems with moulders many times. Production start up has taken place and during the next 3 to 12 hours has effectively settled down to produce quality components with high yields. Then, for no apparent reason, occasional short moulding occurs or the moulding machine alarms out because of an out-of-tolerance value, namely, melt cushion, injection pressure value or screw recovery time.

The presence of the low values indicates that the seal between the sleeve and pressure back ring is non-existent, and that the volume of molten material supposedly contained in front of the screw during holding pressure application has been lost by being forced backwards within the metering section of the Archimedean screw, which gives a corresponding reduction in injection pressure value. For no apparent reason, the loss of material then stops and the screw tip functions again and gives good quality mouldings.

These issues are not so prevalent with materials such as PS, PC, PMMA, HIPS, ABS, PC/ABS, PPO-M, because they belong to the amorphous group of thermoplastics that soften over a wide temperature

Screw tips play a critical role in the quality of mouldings but can sometimes be incorrectly blamed as the source of problems



Problems such as surface splay marks on components made from PC, PMMA, PEI and/or PSU are related to the position of the sleeve within the screw tip assembly prior to closure

range and the presence of solids within the molten material is minimal. However, semi-crystalline materials convert from a solid particle to a liquid melt within a narrow temperature band such as 5°C. This will cause problems if the processing temperature is too close to the melting temperature and if the plasticizing rate is too high.

It is the presence of solid particles that become lodged between the mating faces of the sleeve and pressure back ring that prevent closure. Upon containment between the faces, the solid particle melts, which allows the mating surfaces to come into contact again and the screw tip to function correctly. Poor melt preparation is the true reason for supposed screw tip assembly malfunction.

The way in which the components of the screw tip assembly respond to speed of opening and particularly closing and affect overall performance has long been reviewed by screw tip manufacturers. Demands for ever increasing component consistency and accuracy have necessitated this, particularly when the screw diameter increases from 50 mm upwards; the larger screw/barrel assemblies, the more time consuming and concentrated effort is needed to remove and replace the screw tip assembly.

Furthermore, the larger the screw tip, the greater the cost of replacement. For this reason a wide range of screw tip designs are offered commercially. The ultimate goal of these assemblies is longevity of performance leading to minimal melt volume loss and consistent process and component performance.

Extending screw tip working life

Before we discuss alternative screw tip designs, additions to the current more popular types can be undertaken to extend working life and enhance performance. Longevity of screw tip performance can be influenced by the selection of certain processing conditions, in particular screw back pressure and screw rotation speed.

For materials such as PP, HIPS and GPPS, high peripheral speeds are required to achieve the desired melt homogeneity. High peripheral speeds induce high plasticizing rates and consequently high forces between the component surface of the screw tip. Furthermore, the selection of high back pressure values of 120 bar specific and above (often necessary for master batch dispersion) also generate high forces within the screw tip assembly.

These forces induce friction leading to high steel surface temperatures at the point of dynamic contact. The high temperatures reduce the surface hardness and result in aggressive wear over a short period of time. These temperatures and/or wear are subsequently reflected in poor component quality. They cause the polymer melt to degrade, which results in brown streaks on the moulding or variable component weight/dimensions due to an increasingly defective operation over a period of time.

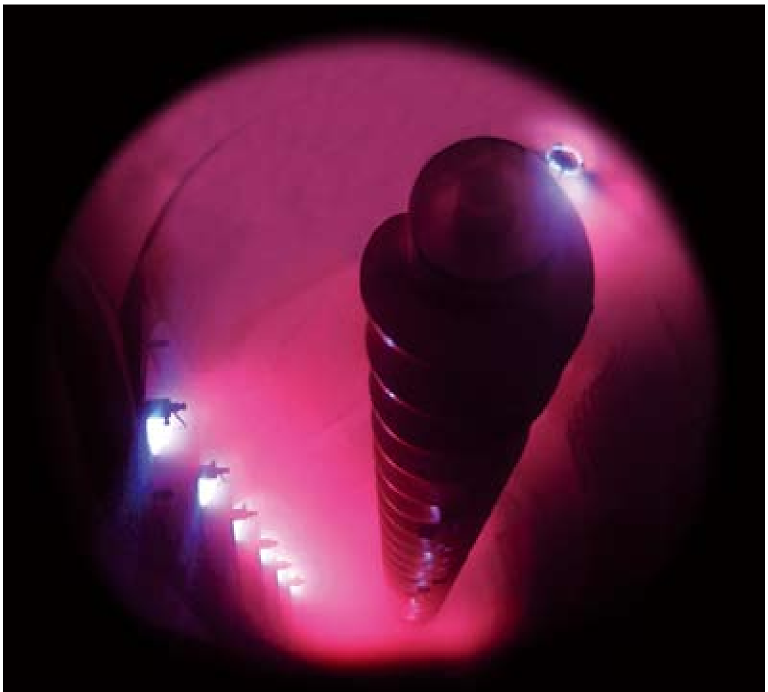
It is for this reason that the optimum screw back pressure value must be determined for the required screw peripheral speed. Where high peripheral speeds are required, physical vapour deposition (PVD) surface coating technology such as TiN or CrC is employed as an alternative to a different design of screw tip. Where the rate of wear is important, particularly with validated processes for high precision, optical, pharmaceutical and medical components, assessment of wear needs to be recorded and verified.

The effect of the PVD micron coating layer allows the friction derived between the mating surfaces to be nullified, and thereby prevents the high temperatures normally generated. Moreover, depending on the type of coating used, contact temp-eratures of 900°C to 1,000°C can be resisted. Usually temperatures above 450°C and up to 500°C cause insurmountable problems through tempering to a typically hardened steel surface of 54-58 Rockwell C.

Such a loss in surface hardness quickly leads to wear taking place. Many processors are now expected to formally log the extent of wear incurred to the components of the screw tip assembly during its working life. This wear is often correlated with the depreciation in process/product capability.

A simple method is to weigh, measure and record each component prior to installation of the newly manufactured screw tip assembly. At pre-determined intervals, that is, every 4,000 production hours, the

PHOTO: SULZER METCO



The use of PVD surface coating technology can be a good solution where high peripheral screw speeds are required

screw tip assembly can then be removed and cleaned by an ultrasonic or fluidised bed technique. Each component is then visually inspected, reweighed, measured and recorded for comparison with the original values. Any discrepancy indicates wear during production, the extent of wear indicated by the percentage change that is calculated.

Before removal for inspection, a process capability study is usually performed so that performance correlation can be undertaken, often to demonstrate to authorised validation bodies that the equipment being used is compliant.

Further discussion of screw tip technology issues, including alternative designs, continues in the next article.

More information

This is the seventh 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**. John Goff is Managing Director of G&A Moulding Technology.

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