Selecting the right screw speed and capacity

In the fourth of his articles on process optimisation, moulding expert **John Goff** looks at the important issue of screw speed and capacity

As explained in our previous article, screw surface speed takes into account the diameter of the screw, the material being processed and the geometry/design of screw employed.

The majority of the screws employed within the moulding industry are based upon a general purpose (GP) design type. However, although all injection moulding machine manufacturers produce a GP screw, each design is not identical across the range of machines available.

In essence, the design employed for a GP screw is commonly based upon a working or effective screw length of 20:1, meaning that the number of turns created along the working length is equivalent to 20 times the diameter. This is also based upon the distance (pitch) between each flight being equal to the diameter of the screw.

Therefore correlation with the screw surface speed generated based upon a rotation speed can be expressed by the simple formula:

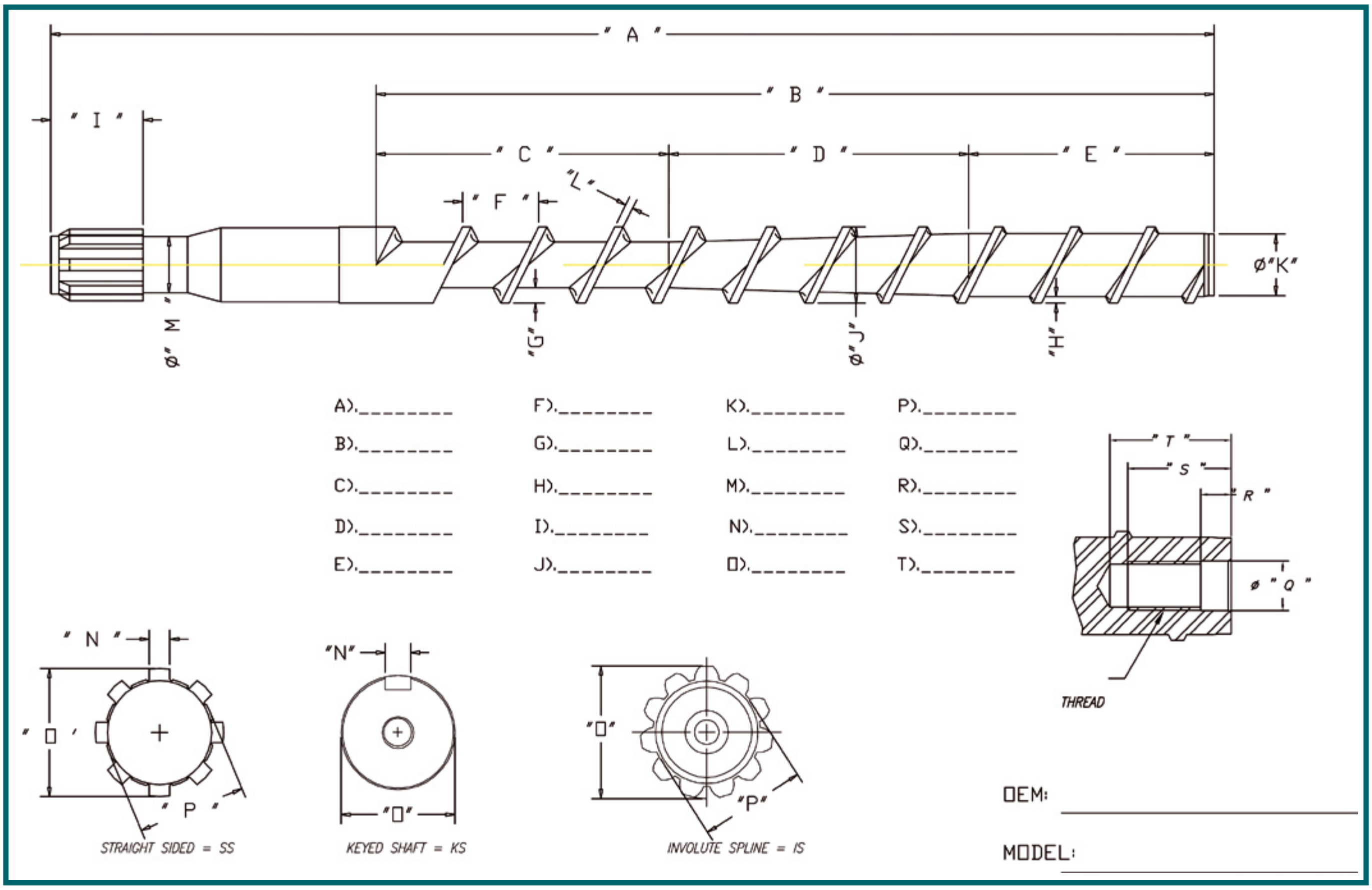
$$\text{Screw surface speed (mm/sec)} = \text{screw rotation speed (rpm)} \times \text{screw diameter (mm)} \times \pi/60$$

Selection of the screw surface speed value plays an important part in both process consistency and cycle time. Quite often there is a trade-off between consistency and screw recovery time. Most moulding processes are performed in a sequential mode, meaning that each segment of the cycle needs to be completed before the start of the next. This principle very much applies where the screw is required to reach its final stop position, irrespective of the duration of the cooling time before the mould tool is opened for part removal.

Fast cycling processes utilise moulding machines that adopt the parallel operation mode whereby two or more elements are simultaneously undertaken, meaning that the screw does not need to return to its final position before opening of the mould tool.

In order to achieve the required cycle time where sequential operation takes place, selection of screw speed becomes vitally important, particularly if a large percentage of the barrel capacity is employed. The

Getting the right screw size and configuration plays a critical role in quality mouldings (*photo: KraussMaffei*)



The screw configuration plays a critical role in the plasticization process (*drawing courtesy of Cooper Technology*)

longer the screw stroke, the greater the tendency to raise the screw rotation speed above recommended values.

Tradition often dictates selection of the screw rotation speed is governed by the cooling time selected. Put simply, as long as the screw returns to its final position just before the cooling time elapses, then the speed is adjusted to suit this requirement, irrespective of whether such speed value is detrimental. In fact, each thermoplastic material has its own particular recommended screw surface speed range. Values outside this range can lead to melt inhomogeneity through either the lack of frictional energy or the inability of the material to absorb the necessary conductive heat energy. Therefore, screw rotation speed is dependent on the material and screw diameter, with too low or too fast a speed significantly affecting process stability and capability.

As previously mentioned, shot capacity can have a controlling factor on screw speed selection because the longer the distance the screw has to recover, the more time it takes. For optimum performance, shot capacities of 25% to 50% are preferred. Capacities from 50% to 65% are used, but with a loss of process capability and component quality standards.

Moulding processes that utilise shot capacities above 65% tend to encounter distinct quality and cycle time issues. Quality issues of poor surface finish in the form of silver streaks are particularly encountered when processing amorphous materials such as PC, PMMA, ABS, PC/ABS, PEI, cellulosics, and to a lesser extent PS. These silver streaks are a result of poor plasticization, but are often misinterpreted as the material being inadequately dried.

With semi-crystalline materials, the quality issues are occasional short mouldings particularly with PP, HDPE, PA and PBT when using cycle times up to 20 seconds. These shorts are a result of the material not being fully melted due to the lack of conductive energy; the dwell time of the material in the barrel is simply too short.

When trying to overcome such issues, the barrel temperatures are often increased (in some cases significantly) which results in a much higher melt temperature than required and this additional heat energy is then transferred into the mould tool. In order to keep to the specified component quality requirements, this extra heat has to be removed in some way during the filling, packing and cooling phases of the cycle. More often than not, the cooling capability of the mould tool is inadequate and necessitates an extension of the holding pressure time and/or cooling time, in turn extending the cycle time.

Nowadays a different approach is recommended for the manufacture of components which necessitates fast cycles. Particularly with thin-walled components and/

or closures, there is a distinct trend for barrel capacities to be reduced from 25-50% to 15-30%. This enables the screw recovery time to be shortened, thus allowing the screw to return to its final stop position before completion of the cooling time and with the correctly selected screw surface speed. Keeping the material inside the barrel slightly longer, at the recommended optimum melt temperature, provides a much more stable base from which to produce. As the cycle times are short, the time that the material remains in the barrel is not excessive.

A major criteria for the lower shot capacities is that the type of machine used should be able to cope with the ability to attain a particular injection speed setting within the smaller screw stroke. This means that the rate of acceleration and deceleration of the screw to and from a selected speed is very important, hence the movement towards servo-hydraulic and servo-electric machines from standard valve actuation and pump controlled machines.

For an optimised process, the screw recovery operation should be completed within 1 to 2 seconds of the end of the cooling time. This statement does not infer that for components that necessitate relatively long cooling times very slow screw speeds are to be used. As 70% of the melt plasticizing energy is derived from the screw, too low a screw rotation will result in inadequate melt preparation, process inconsistency and poor component quality. Therefore, the selection of a correct screw rotation must correlate with the optimum screw surface speed. Where screw recovery is considerably less than the selected cooling time, the screw delay option should be used; for example, a selected cooling time of 22 seconds, a screw recovery time of 8.4 seconds and a screw delay time of 11.6 seconds.

Screw designs that are different from the classical, general type will be discussed in more detail in a forthcoming article.

More information

John Goff is managing director of G&A Moulding. This the fourth part of his series of articles looking at process optimisation and troubleshooting. The first, second and third parts can be see **here**, **here** and **here** respectively.

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