In the latest article in his series on process optimisation, moulding expert **John Goff** discusses how to obtain best performance from the non-return valve assembly found at the front end of the Archimedean screw

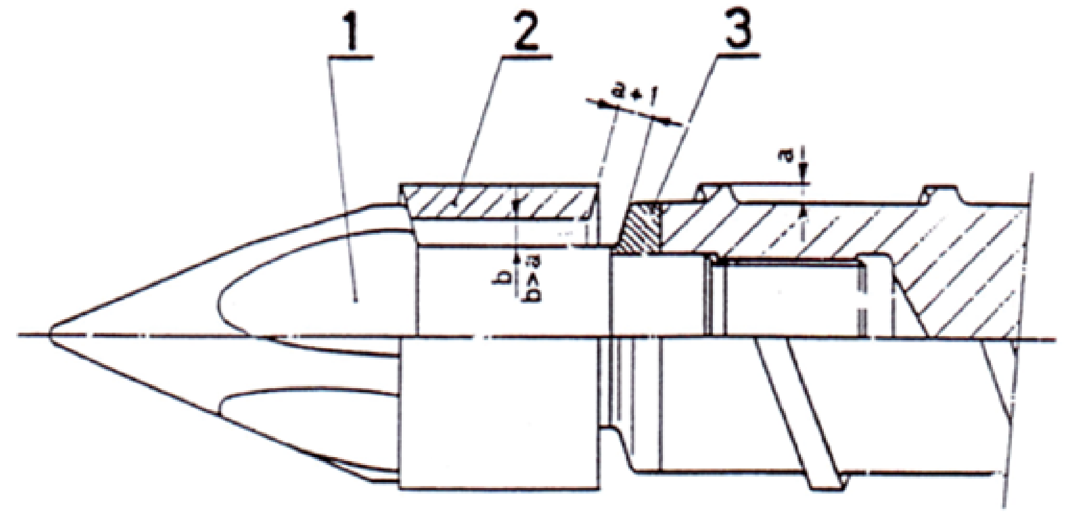
Achieving optimal functioning of the non-return valve

Following determination of the most effective **back pressure value** to be used, another piece of the processing jigsaw for consistent moulding manufacture is the effect of the type, design and operation of the non-return valve assembly, which is located at the front end of the Archimedean screw. This non-return assembly is also called the backflow valve, ring valve, check valve, castellation valve or the SK valve, to name a few of the terms used for this device, and it is important to achieve the best performance from it. Its function is three-fold: to allow sufficient volume of material to pass through the screw tip assembly with minimal disturbance to the molten plastic, to prevent leakage of molten plastic during its closing operation and, once closed, to ensure it remains fully sealed.

In reality, this mechanical device is designed to wear and will do so during its working life. The extent of wear and its working life is dependent on its design, the processing conditions selected, and the type of polymeric material, steel and surface coating employed. The generic screw tip assembly is a three-piece assembly that contains a torpedo, a pressure back ring and a sliding ring (sleeve). Figure 1 shows what is typically offered by major machine manufacturers. Special designs are available to enhance performance and component quality and these will be discussed in the next article.

Each screw tip component has a specific function. The torpedo (1) has a left-handed thread that is screwed into the end of the Archimedean screw and therefore contains the circular sleeve (2) between its head and the pressure back ring (3). The head of the torpedo is streamlined and scalloped to allow molten polymer to pass around with

Figure 1: The generic screw tip assembly contains a torpedo (1) screwed into the end of the Archimedean screw, which contains the circular sleeve (2) between its head and the pressure back ring (3)



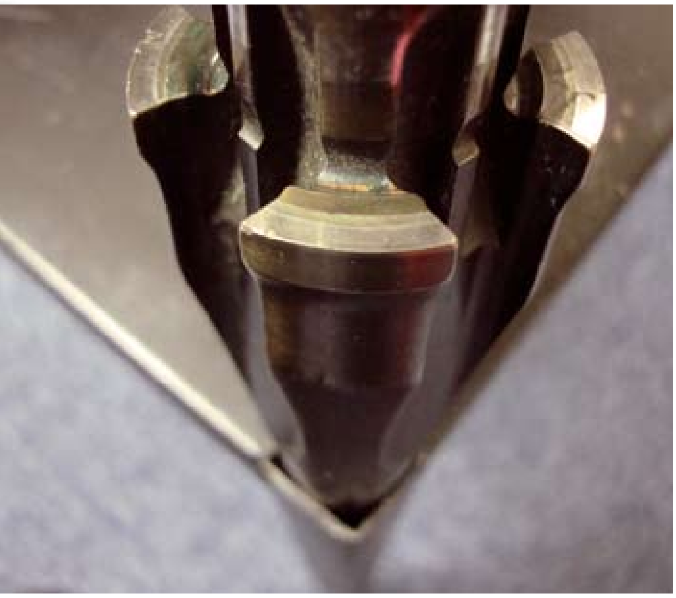


Figure 4: Friction between the mating surfaces of the rotating torpedo and sleeve leads to wear of the inner diameter or the torpedo shank

the minimum of flow disturbance (resistance) and adherence. The shank diameter of the torpedo is such that the gap between the inner sleeve is sufficient to allow the molten material to pass through again without encountering excessive shear and/or rapid increases in melt temperature. The internal bore of the sleeve varies from a parallel to a tapered design, depending on the preference of the machine manufacturer.

The actual operation of the valve falls into two distinct functions: fully open and fully closed. On screw rotation to start refilling of the barrel, the polymeric material is transported from the feed to the metering section of the screw in a solid, semi-solid and molten state. The material becomes fully molten after it leaves the compression section and enters the metering section, and the molten material is forced into the tip assembly. An in-depth explanation of screw geometry and performance will be covered in a future article in this series.

For the generic design to function, the sleeve component needs to have a sliding or transitional force fit with the inner surface of the barrel. The actual clearance between the two components ranges from 20 to 60 microns, depending on the diameter of the screw. The gap needs to be sufficiently small to prevent the molten material (passing between them) from sliding, but not large enough to cause leakage or affect its operation. Values above and below this range lead to malfunctions and inconsistency and result in defective and inconsistent mouldings or thermal degradation of the polymeric material. Furthermore, too close a fit often initiates premature failure of the sliding sleeve component with hairline cracks forming and/or erratic closure of the screw tip assembly.

In addition to rotation during screw recovery, the sleeve has to move linearly backwards during the injection phase towards the angled or flat face of the pressure back ring to create an effective and hermetic seal. This movement is often termed the "stroke" of the sleeve. When in fully forward position with the front face of the sleeve in contact with the head of the torpedo, a gap appears between the sealing surface of the pressure back ring and the corresponding surface of the sleeve (Figure 2); this is described as being in the "open" position. Consequently, when the two mating sealing faces are forced to make contact, this position is referred to as "closed" (Figure 3).

The three-piece assembly is subjected to dynamic and static forces and a major issue is the presence of friction between the mating surfaces of the rotating torpedo and sleeve. These forces are the result of molten material being pushed through the gap between the inner diameter and torpedo shank and subsequently the scallops. Significant wear to one or both components can take place in an extremely short time and the temperature at the point of contact between the rotating surfaces has a significant influence (Figure 4).

In an attempt to minimise the high contact temperatures, the internal configuration of the sleeve varies

Figure 2: Open position, showing the gap that appears between the sealing surface of the pressure back ring and the corresponding surface of the sleeve when the front face of the sleeve is in contact with the head of the torpedo

Figure 3: The closed position when the two mating sealing faces are forced to make contact

Release the pressure - just like floodgates, non-return valves play a critical role in flow control

from cylindrical to a tapered cone, depending on the type used. Furthermore, the working performance of the sleeve requires a change in shape from the manufactured, conventional cylinder to that of a barrel-shaped profile. This is because of the hoop stresses that develop within the inner bore, which force the sleeve to deform and make point contact with the opposing barrel surface. This also allows the mating surfaces of the sleeve and pressure back ring to positively seal against each other. Therefore, the higher the screw's rotational speed during screw recovery, the faster the injection velocity, and the higher the holding pressure. This in turn leads to greater volume of shot and the corresponding melt homogeneity will influence the performance and working life of the screw tip assembly. From a practical setting point of view, to achieve process and component consistency, the function of the tip assembly must be consistent in each cycle. With the generic design there are various machine settings that need to be objectively searched.

The terms "decompression" or "suck back" are commonly known in the moulding industry and it is believed that their main objective is to prevent nozzle or gate drool when producing components using fixed probe or thermal gated hot runner mould tools. By simply pulling the screw linearly backwards on cessation of screw rotation, the pressure created in front of the screw tip assembly and/or hot runner manifold during screw recovery is allowed to decay as a result of the increase in volume created by the backward movement of the screw. In fact, the true reason for using decompression is to obtain shot to shot consistency. However, the increase in volume does allow the inherent pressure to decay, thus preventing nozzle drool. Of more significance is the extent to which the backward movement set on the moulding machine corresponds to the position of the sleeve within the screw tip assembly.

When processing, it is important that the distance between the sealing faces of the sleeve and pressure back ring is consistent each cycle. By pulling the screw backwards an optimum distance, the effect of pressure decay becomes apparent and the stroke between the faces remains consistent.

During the first few millimetres of forward stroke of the initial injection phase, molten polymer is forced backwards along the cylinder until the two sealing faces of sleeve and pressure back ring meet. If this distance varies from cycle to cycle, then the volume injected into the mould tool will also vary (often seen in the variation in melt cushion value). Therefore, from a performance viewpoint, containment of this material loss should be kept to a consistent minimum on a cyclical basis.

The distance the screw is pulled backwards often corresponds with the total distance of sleeve movement, however caution is needed. The decompression stroke used may not be the same as sleeve movement because the visco-elastic behaviour of the molten thermoplastic material must also be taken into account. For this reason, the decompression stroke is sometimes longer than the actual stroke of the sleeve. In conjunction with the decompression stroke, the speed at which the screw is pulled linearly backwards greatly influences the control of the position of the sleeve within the screw tip assembly.

Monitoring the actual screw position on completion of the decompression exercise is important because this indicates the final position the screw stops at prior to injecting volume into the mould tool the next cycle.

Optimising the most effective decompression stroke and speed settings is the basis of consistent moulding. The next article in this series will discuss the issues involving decompression, screw tip technology and related part qualities.

More information

This is the sixth 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, here and here, respectively. John Goff is Managing Director of G&A Moulding Technology,

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