The Tip Decides

Avoiding Wear in Non-Return Valves

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Non-Return valves play a critical role in the success or failure of processes. Fundamental studies of wear make it possible to find remedies and to increase the service life through selective parts modification.

Non-Return valves are extremely critical parts in injection moulding processes. They prevent the melt from flowing backwards during injection into the mould. The most common design is the annular non-return valve (Fig. 1) in which the pressure build-up in the antechamber in front of the screw presses a sealing ring against a stop ring, thereby isolating that space from the screw channel. During metering, the higher pressure in the screw channel forces the sealing ring against the flights of the screw tip with the result that the melt can flow into the screw antechamber. The screw tip moves at the speed of the screw while the sealing ring is either stationary on account of friction at the cylinder wall, or rotates at a lower peripheral velocity.

Worn Flights Cause Fluctuations in Processes

The relative motions of the screw tip and the sealing ring cause increased wear of the flights. This leads to stroke enlargement, which manifests itself in fluctuations in melt cushion. Wear at unsuitable non-return valves decreases process stability. Frequent replacement of non-return valves means production breaks and high costs for users.

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Wear Mechanisms Superimposed on Each Other

Wear shows up in the form of wear debris and in changes of material and shape of the tribologically stressed surface, with material loss being known as the amount of wear and its inverse as the wear resistance.

When stresses work collectively on the elements of the tribological system, both physical and chemical processes occur. These take the form of energetic and material interactions between base surface and mating surface. When influenced by intermediate material and ambient medium in real cases of wear, the main wear mechanisms (Fig. 2) such as adhesion, abrasion, tribochemical reactions and surface destruction rarely occur independently but tend to be superimposed on each other.

Adhesion

When base surface and mating surface are in direct contact, considerable stress is generated in the regions of micro-con-

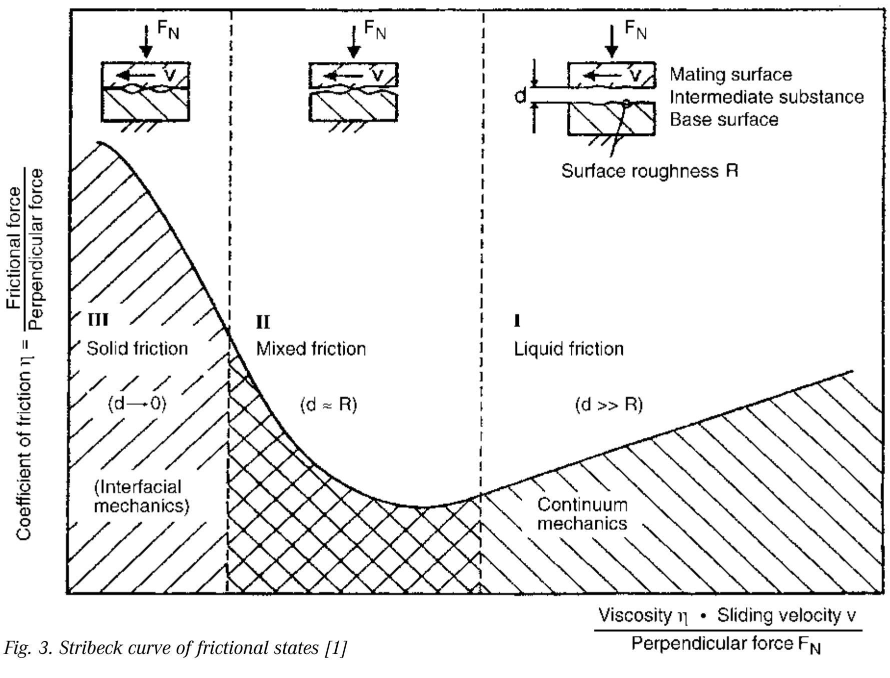

Fig. 3. Stribeck curve of frictional states [1]

tact that are enhanced by the tangential relative movements of the contact partners. These stresses cause plastic deformation of the roughness peaks. This can lead to destruction of the adsorption or reaction layers adhering to the surfaces between which only van der Waals forces act at a distance of less than 10 nm. Metallic and covalent bonds form between the unprotected surfaces. Such adhesive interactions are particularly marked between "pure" surfaces.

Abrasion

When a hard body penetrates into the softer surface of the base surface, the relative movements create furrows. The hard body may be a mineral particle, a micro-roughness on the mating surface or debris that has already solidified. Different material pairings or surface roughness are possible causes of abrasive wear.

Surface Destruction

Frequent mechanical cycling in the surface regions of a material leads to surface destruction or fatigue wear. The alternating stress causes changes in microstructure, crack formation and growth and may lead to debris formation when several cracks run together.

Tribochemical Reactions

Tribo-oxidation is a chemical reaction between base surface or mating surface with components of the intermediate material and/or the ambient medium as a result of tribological stress. This results primarily in changes to the external boundary layer. The wear can be reduced when the reaction layers prevent direct metallic contact between base surface and mating surface. However, if the reaction layer becomes detached and forms loose debris, the amount of wear may even increase since abrasion and adhesion may occur.

Conventional Selection Methods are Inadequate

Usually, the materials for non-return valves are chosen on the basis of trials involving the DKI's plate-like wear nozzle. In this method, large local shear stresses are generated in a gap of defined dimensions that is formed by two swappable plate-like test specimens. The weight loss determined on the test specimens is taken as a measure of wear. However, since the tribological stress of non-return valves differs from that in the plate-like wear nozzle, and since wear resistance is not a material-specific characteristic but rather a system-related property, this test set-up is only of limited use for choosing materials.

A More Realistic Experimental Set-Up ...

Battenfeld Kunststoffmaschinen, Kottingbrunn/Austria has therefore designed an experimental set-up on a 40 mm screw that reproduces the conditions which occur in normal injection operations. The replica injection cycle consists of 6 s metering followed by a pause lasting 12 s. The back pressure usually exerted by the melt on the screw during metering is simulated and varied by a flow-control nozzle.

Pressure sensors measure the melt pressure in front of and behind the sealing ring and so determine the pressure drop. Infrared sensors located at the flight shoulders of the non-return valves determine the temperature.

... Provides Better Information

From these trials, it has proved possible to deduce fundamental relationships and various characteristics or conditional equations. Thus, one equation from the pressure drop across the sealing ring during metering makes it possible to determine the pressure with which it makes contact with the flight of the screw tip. Apart from the contact pressure, the temperature at the point of friction is crucial to wear. To this end, either the actual melt temperature is measured directly or a model computation is used.

Melt Lubricates and Cools Simultaneously

The model-based method of estimating the temperature at the points of friction is calculated with an equation that is based on the supposition of solid friction between the screw tip and the sealing ring. It should be noted that the melt not only acts as a lubricant during metering but also cools the point of friction. As calculated in this way, these temperature values match those returned by metallurgical studies on worn non-return valves.

Polyolefins Are Particularly Dangerous

The experiments performed on various thermoplastics (including fibre-glass-reinforced grades) show that polyolefins, in particular (PE, PP), cause enhanced wear on the flight of the screw tip.

Collective stress
Collective stress connotes the forces, speeds, temperatures and other influences affecting the tribological system.

Tribology
Term used to describe the scientific study of friction, lubrication and wear.

Tribological System
A tribological system comprises base surface and mating surface, intermediate material and a surrounding medium.

Stribeck Curve
The Stribeck curve is a diagram used in wear studies in which the coefficient of friction is plotted against a combination of parameters (usually oil viscosity, slide rate and perpendicular force).

Temperature Peaks Through Tearing of Lubricating Film

As may be seen from the Stribeck curve (Fig. 3), increasing normal force and decreasing viscosity conduce to a state of solid friction. The reason is the melt film that forms between the screw tip and sealing ring during metering. This tears in the case of PE and PP because of the high shear rate in the gap and the resultant decreasing viscosity with the result that the melt surfaces make contact. This friction causes temperature peaks, as shown in the experimental diagrams from the trials on PE (Fig. 4) and PP. The lubricating film builds up at irregular intervals, but collapses soon after, which causes the temperature to rise again.

High Forces Promote Adhesive Wear

The pressure drop across the sealing ring is roughly 20 bar, equivalent to a contact pressure of around 600 N when allowance is made for its geometry. These high forces, together with the temperature peaks, promote adhesive wear. Brief welding of screw tip to sealing ring is the consequence. When these come apart again, fine particles are ripped out of the material at the same time and these may be detected in the melt. As a result, high abrasive wear of the screw tip occurs even when only small amounts of polymer have been processed.

Universal non-return valves cannot be used without restriction for all polymers. Drawing on this knowledge, Battenfeld has developed an improved screw tip that is suitable for a range of polymers. When tested (Fig. 5), this non-return valve failed to give rise to temperature peaks. From the fact that the metering motor has a lower driving load of roughly 1 kW, it may be inferred that much less energy is lost due to friction compared with the case for improperly used screw tips.

In the new non-return valve (Fig. 6), four times the amount of metered polymer under the tighter experimental conditions was processed without showing any wear. This leads us to expect a much longer injection-moulding service life.

Fig. 1. Annular non-return valve: The pressure build-up in the screw antechamber presses the sealing ring against the stop ring and so isolates that space from the screw channel [1]
Schneckenspitze = Screw tip; Sperrring = Sealing ring; Anschlagring = Stop ring

Fig. 2. The principal wear mechanisms usually are superimposed [2]
Adhäsion = Adhesion; Tribochemische Reaktion = Tribochemical reaction; Oberflächenzerrüttung = Surface destruction

Fig. 4. Characteristic of unsuitable non-return valves: temperature peaks indicate metal-metal contact, high pressure drop suggests high contact pressure and a large drive load on the metering motor reveals energy losses through friction
Drehzahl = Speed; Massetemperatur = Melt temperature; nach = after; vor = before; Leistung Dosiermotor = Drive motor load; Dosierzeit = Metering time

Fig. 5. Enhanced non-return valve: no temperature peaks, lower values for pressure drop and drive load
Drehzahl = Speed; Massetemperatur = Melt temperature; nach = after; vor = before; Leistung Dosiermotor = Drive motor load; Dosierzeit = Metering time

Fig. 6. Even when four times the amount of plastic is processed, the improved screw tip shows no signs of wear