Model Test Systems. Wear on plastics processing machines cannot be simulated. Wear studies are therefore carried out on model test systems. Conventional methods are often time consuming and costly. Two innovative, realistic test apparatuses now permit more precise and time-optimised studies.

Wear Testing on Plastics processing Machines

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Wear testing methods extend from industrial trials on test rigs with original parts to testing on model systems. Field tests are unfeasible for systematic gathering of knowledge about fundamental wear because they are excessively material and time consuming, and expensive. The wear tests are therefore carried out on model systems, and the results obtained are applied to practical cases. Wear testing on substitute systems, such as the model test apparatus, offer the advantage that the multiparameter operating states and influencing variables of the original systems can be reduced to significant parameters. The complex processes of an actual tribological system are simplified and analysed into elementary basic processes. The first of these steps permits the inexpensive study of wear phenomena, and thereby the systematic gathering of information for wear research. Because of the plastication unit's complexity as a tribological system, a range of different test apparatus is required for characterisation of wear phenomena. The test methods developed for this can be classified into adhesive wear, wear by solid or plasticated moulding compounds, and corrosion [1, 2].

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Push-pull Tribometer

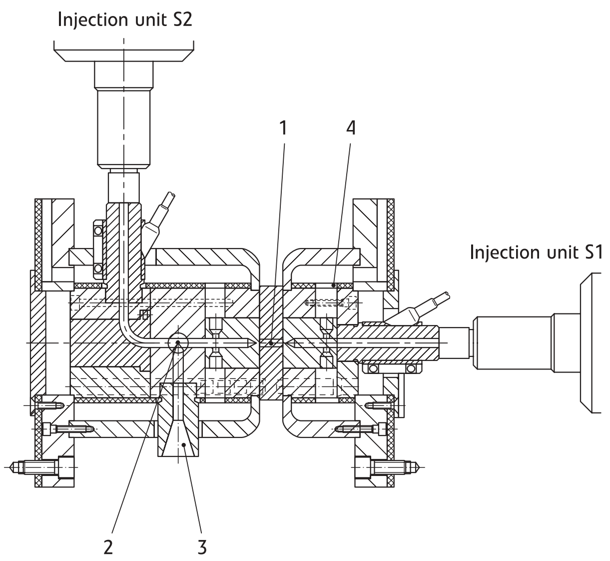

Fig. 1. Design of the push-pull apparatus (1 test specimen, 2 melt valve, 3 outlet nozzle, 4 pressure and temperature sensors)

More flow cycles in the same time

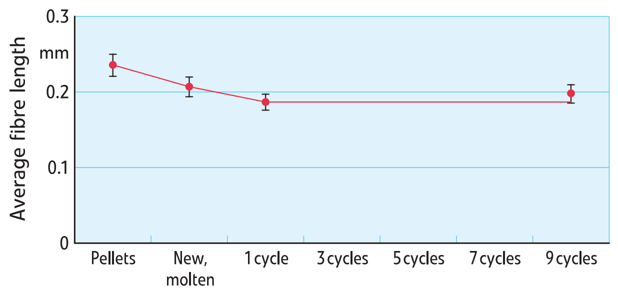

Fig. 2. Reduction of the glass-fibre length in the push-pull apparatus

Wear and Corrosion Test Methods

In most of the corrosion test systems used until now, the pellet moulding compound is melted and the test specimens are wetted with the melt and then left in the melt for a defined time. The melt is not exchanged during this time. This is the principle behind the test systems from Calloway, Knappe/Mahler and Mosle [3, 4, 5]. They differ according to the melting process and the possibility of compressive loading – in addition to temperature loading. The Mosle apparatus permits relative movement between the specimen and the melt, however only with very low flow rates, and therefore there are no loads comparable to the shear stresses in the plastication unit [5].

All apparatuses require long test times. Multiple specimens are always loaded simultaneously. The decreases in weight are determined as the parameter for quantifying wear [4]. However, because of the low weight decrease (of the order of milligrams), the measurement error for gravimetric analysis is high. The samples are therefore also optically assessed by optical, electron-optical and in some cases surface analysis. Only a limited quantitative indication of corrosion is possible.

The former plate apparatus of the German Institute for Polymers (DKI), Darmstadt, permits investigations in the melt range for choosing materials [2]. With this method, two plate-shaped test specimens form a gap (0.2–0.4 mm), through which a plastic melt flows. The wear resistance of materials compared for a particular processed moulding compound and its additives can thus be determined under realistic conditions. The studies with the plate apparatus model the processes in the melt channel between the cylinder wall and screw flight or in a hot channel.

The advantage of the plate apparatus lie in the simple geometry of the flow cross-section, which permits constant rheological conditions during the entire process. The DKI plate method realistically reproduces the synergistic abrasive-corrosive complex loads as well as the degradation loading of the melt.

Simultaneous loading of ten specimens

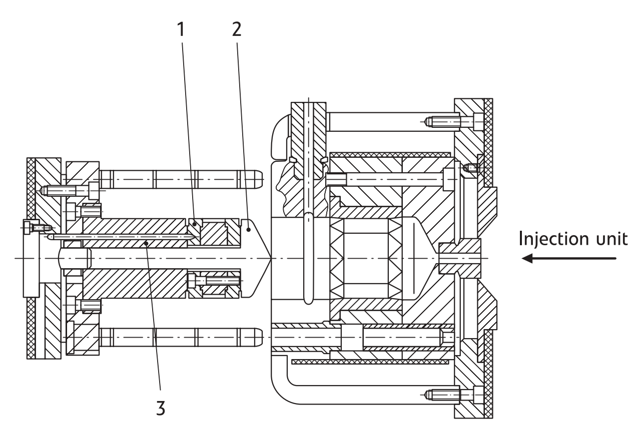

Fig. 3. Apparatus for corrosion studies in an open state (1 test specimen, 2 manifold head, 3 connection for electrical potential)

Corrosion effect of chlorinated polyvinyl chloride

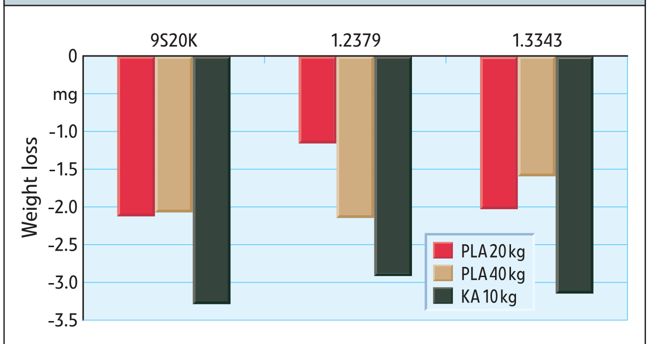

Fig. 4. Weight loss of different steels in corrosion tests with the DKI plate apparatus (PLA; moulding compound throughput 20 and 40 kg) and the corrosion apparatus (KA; moulding compound throughput 10 kg)

Push-pull Tribometer

The DKI's work was targeted at developing improved model test methods for the wear testing of steels used in plastics processing machines. The improved model apparatuses based their measurement principle on the DKI plate apparatus. To obtain better measurable weight losses, the surface/volume ratio of the test specimens was increased in the new apparatus. In addition, the material volume can be minimised while still achieving high wear by allowing the same material to flow multiple times over the platelet. In addition, the cycle times were reduced by means of reduced plastication times and machine movements.

In the push-pull apparatus, the test specimens are integrated in a hot-runner block in a two-component injection moulding machine (Fig. 1). Unit S1 plasticates and meters the material. Then the melt from injection unit S1 flows between the test specimen plates into unit S2. This process takes about 4 s at a pressure of about 800 bar. Immediately after this injection operation, unit S2 injects the melt back to S1 (push-pull method). Since the melt is heated dissipatively as it flows through the 0.3 mm test gap, the temperature of the melt in the hot-runner block is monitored during the tests. After multiple push-pull cycles, a melt valve is operated and the melt is ejected from the block.

With a doubling of the injection volume flow rate in comparison to the plate method used until now, an injection operation takes 4 s. In approximately the same time as it takes for the melt flows over the plates once with the previous method (total cycle time approx. 30 s), about 6 to 7 flow cycles can be implemented (Fig. 2).

The number of possible push-pull cycles depends on the acceptable melt-temperature change, the thermal stability of the melt and, in the case of fibre-filled materials, on the fibre damage occurring. In the case of unreinforced thermally stable moulding compounds, up to nine push-pull cycles can be carried out before the material is damaged by thermal effects and shearing.

Long-term Corrosion Apparatus

With the plant concept of the long-term corrosion apparatus, long experimental times and residence times are intended to determine the corrosion resistance of the test specimens. To allow the additives of the mould compound and their degradation products to act on the test specimens, and thereby to cause corrosive wear, long surface contact times between the plasticated moulding compound and the metal material are implemented with maximum melt residence times. In the test rig, ten test specimens can be tested simultaneously. In addition, a phased abrasive loading is possible in order to remove corrosion layers. The test specimens are electrically insulated so that electrochemical corrosion with electrical voltage can be studied.

On the core is mounted the specimen holder for ten specimens, distributed uniformly around the circumference (Fig. 3). The plate-shaped test specimens are clamped with two adapter rings. A mushroom-shaped manifold head upstream of the specimens distributes the melt uniformly. Together with the core, it forms a flow channel that guarantees identical flow conditions for all specimens. Two different spacings between the test specimens and outer wall were chosen, namely 0.3 and 0.6 mm, which had proven suitable in previous studies with the platelet apparatus.

A small screw machine is used to achieve the shortest possible residence times in the plastication unit and in the feed channels. The corrosion apparatus has been designed for an injection moulding machine with a screw diameter of 18 mm. This achieves a short residence time of less than 25 s in the plastication unit. The machine (Boy 22M) used at the DKI can optionally be operated with conventional cycle times or else in a quasi-stationary manner, i. e. with high shot volumes and high injection and cycle times.

To achieve the abrasion loading, it was assumed that, in order to remove the corroded layers, it is better to apply a high load occasionally than a small load more frequently. In a similar way to the conventional plate experiments, the required load is applied by means of the injection movement of the plastication unit at the end of each cycle. The metered volume of moulding compound is injected very rapidly (10 cm^3/s) over the specimens. The corrosion and wear studies can be carried out with a reduced moulding compound throughput with higher wear rates (Fig. 4).

Summary and Outlook

The two newly developed apparatuses allows studies to be conducted on wear mechanisms, abrasion and corrosion or mixed loading.

In the push-pull tribometer, strong abrasive wear is achieved by means of a push-pull loading of the material. The experiments allow different tribological systems to be compared by means of the weight losses, using a lower material throughput than in previous studies.

Because of the long surface contact times, the corrosion apparatus allows controlled series experiments to be carried out on the corrosive behaviour of various tribological systems. In studies with the corrosion apparatus, too, material and time consumption are much smaller.

By means of the two new apparatuses, systematic wear studies on hard, abrasion-resistant materials (e. g. diamond coatings, hard metals, ceramics), and corrosion studies can be carried out with good resolution. ■

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