INVESTIGATIONS ON THE TRIBOLOGICAL BEHAVIOUR OF ENGINEERING POLYMERS

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Summary: *In the resent research work a sufficient test method was developed to determine the friction- and wear regimes of POM and PA for different testing conditions. Tribological results show indeed there is a positive influence of the friction modifier in the POM and PA by lowering friction- and wear values. From a failure analytical point of view, different wear processes at the polymer surface are observed related to the presence of the friction modifier.*

Keywords: *tribology, injection moulding, POM, PA*

1 Introduction

Different production processes like injection moulding or turning produce different technical surfaces and qualities which lead to different tribological properties for the compounds especially for the frictional regime [1]. For low friction coefficients and low wear rates well-known thermoplastic materials like Polytetrafluoroethylene (PTFE), Polyoxymethylene (POM) and Polyamide (PA) are very common in this field [2]. Besides the material properties, counterparts and the control of the ambient conditions are important to provide best properties for applications. Therefore validation of the frictional regime and transitions to wear regime are from outermost importance and have to be investigated [3].

2 Experimental

2.1 Materials

For this study three materials (POM unfilled, POM and PA with friction modifier) where chosen. The materials were produced via injection moulding and test specimens (pins) were turned out of tubes. In table 1 basic informations about the materials are shown.

Table 1: Basic material properties for all tested materials

Parameter Unit	Density g/cm^3	Young's modulus MPa	Thermal expansion $10^{-6}/K$	Melting temperature $^\circ$
POM	1.42	3100	110	178
POMmod	1.4	3000	110	178
PA+20%PTFE	1.24	2500	-	260

As shown in table 1 the general properties describe the difference between POM and PA. The surface structures of the specimen after production are shown in Figure 1.

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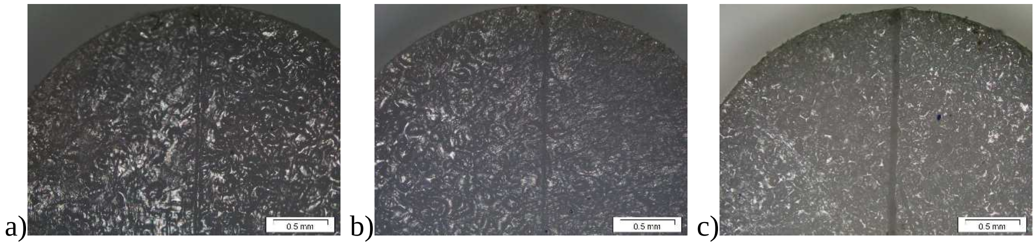


Figure 1: Injection moulded surface of a new A) POM, B) POMmod, C) PA+ $20\,\%$ PTFE specimen

The surfaces shown in Figure 1 represent the casted surface structure from the injection moulding tool and show that the materials have similar topographies.

2.2 Method Development

The tribological investigation of injection moulded test specimens were done via a pin-on-disc Tribometer. To check the influence of the frictional and wear behavior of the injection moulded surface, a precise tribological test method was used to evaluate the range of the frictional regimes for these polymers. The friction and wear tests were performed by using a UMT-2 (Bruker Corporation, Campell, USA) Micro Tribometer for Pin-on-Disc measurements (see Figure 2). To ensure the same friction state the counter bodies for the tests were produced with the same roughness (wear tests: $R_q = 1\,\mu\mathrm{m}$, short term tests: $R_q = 0.3\,\mu\mathrm{m}$, Start/Stop experiments: $R_q = 0.4\,\mu\mathrm{m}$).

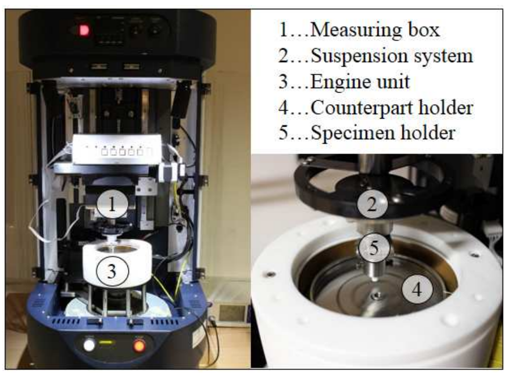


Figure 2: Test rig UMT-2

To characterize the friction coefficient the samples were tested with 0.5 and $1\,\mathrm{MPa}$ and a duration of $16\,\mathrm{hours}$. The velocity was defined with 38 and $135\,\mathrm{mm/s}$. In addition Start/Stop experiments with different velocities (19 and $38\,\mathrm{mm/s}$) and loads (0.5 and $1\,\mathrm{MPa}$) were performed (track $7\,\mathrm{cm}$). Finally short term experiments were done (track $100\,\mathrm{m}$) and the discovered friction coefficients were compared to those found in the long term tests.

2.3 Failure analysis

After testing microscope pictures of the specimens (magnifications: $50\times$ up to $200\times$) were taken. One specimen of each material was chosen to be analyzed via scanning electron microscope (SEM) with a magnification of $20\times$ up to $2000\times$. Therefor the surface of the specimen was coated with a thin gold layer in order to avoid charging.

3 Results & Discussion

3.1 Wear tests

Wear tests with a duration of 16 hours and a variation of velocity (38 and $135\,\mathrm{mm/s}$) and load (0.5 and $1\,\mathrm{MPa}$) provided the basic friction coefficients and wear rates are displayed in Figure 3.

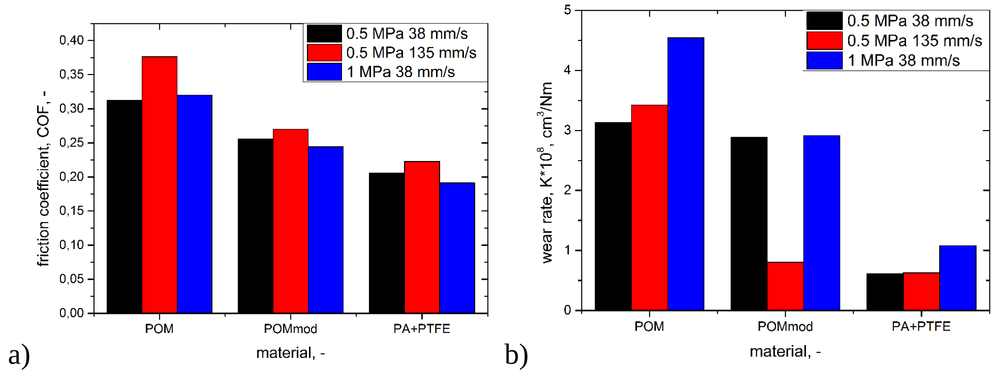
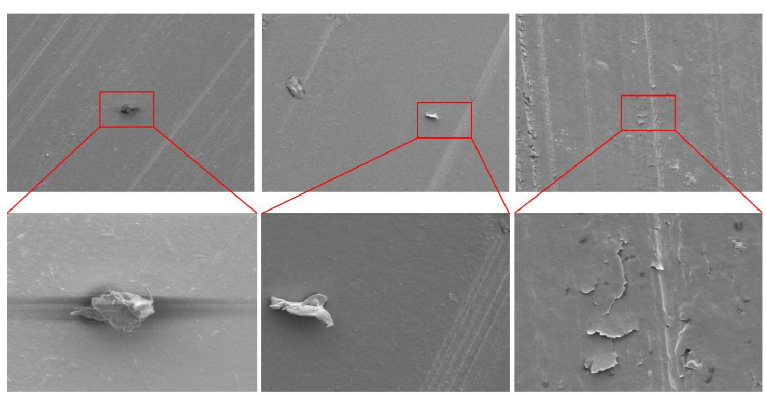


Figure 3: Speed and load dependency (a) of the friction coefficient (COF) and the wear rate (K) at long term wear tests (b)

The COF results show (see Figure 3a) that the influence of the material and friction modifier is clear visible and the PA type shows the minimum values of the COF related to the load and velocity. In Figure 3b the wear rate shows highest levels for all three materials with $1\,\mathrm{MPa}$ and $38\,\mathrm{mm/s}$ loading conditions. The wear results show, that there is a clear difference between filled and unfilled POM, as well as between POM and PA. The presence of fillers is obvious and leads to a lower friction and wear level for PA and filled POM compared to unfilled POM. To compare the tribological results with the failure mechanisms at the surface in Figure 4 SEM pictures after testing are shown.



a) b) c)

Figure 4: Surface of the a) POM, b)POMmod, c) PA+ $20\,\%$ PTFE specimen after a $16\,\mathrm{hours}$ test with $12.4\,\mathrm{N}$ load and a velocity of $38\,\mathrm{mm/s}$ recorded with SEM and a magnification of 200x and 1000x

The pictures in Figure 4 show that the surface of unfilled POM (a) is more eroded than the filled one (b). The presence of PTFE in PA is clearly visible because of the folded surface structure (c).

3.2 Friction tests

In order to describe the frictional behavior of the materials short term tests as well as Start/Stop tests were performed and shown in Figure 5 to compare with long term experiments.

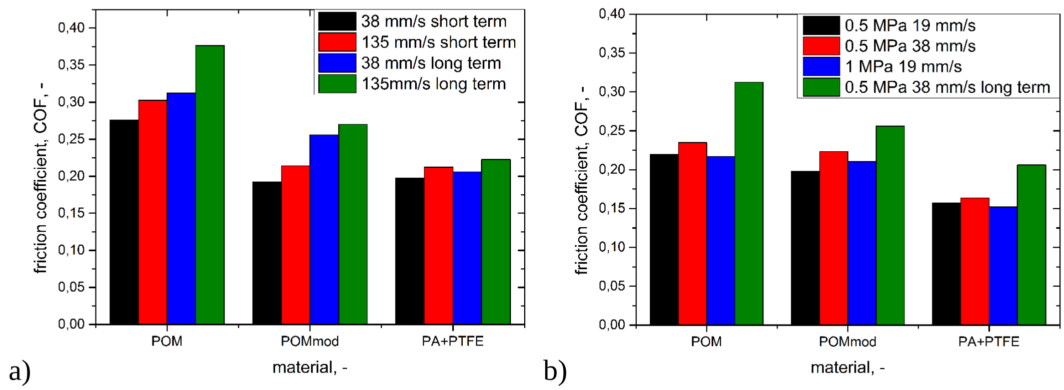


Figure 5: Speed and load dependence of short term testings compared to long term testings (a) and Start/Stop experiments (b)

As in the long term experiments the friction coefficient showed a dependence related to the velocity and load during the tests, but the base level of the short term POM samples friction coefficient were significant lower than in the long term friction tests (see Figure 5a). There was no fundamental change of the friction coefficient of PA because of the presence of the filler. The Start/Stop experiments with different velocities (19 and $18\,\mathrm{mm/s}$) and loads (0.5 and $1\,\mathrm{MPa}$) show that the friction coefficient is attached to the testing speed, but not to load differences (see Figure 5b). The basic level of the friction coefficient in Start/Stop experiments is also lower than in long term tests. The graphs in Figure 5 show, that the roughness of the surface has an immense influence on the level of the COF. As found in the literature there is a strong relation between the roughness of the counterpart and the friction coefficient [4]. The higher the surface roughness is, the higher the COF is.

4 Conclusion & Outlook

The current work shows, that there is a positive influence of fillers in POM and PA. Fillers in POM and PA are helping to decrease friction as well as wear parameters in tribological experiments. The tests also showed the great influence of the roughness of the counterparts. Furthermore the velocity had an influence on the friction parameters. The parameters increased with rising the velocity. Further measurements under different lubricated states will be performed in the ongoing project.

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