ABRASIVE WEAR OF ENGINEERING POLYMER GEARS

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Abstract: The paper introduces first some commonly used engineering polymers from the practical life and selected for the further investigation. Regarding the different ranking of polymer/steel pairs from the point of friction and wear obtained by many different tribometers and test-system, it would be difficult to choose the best polymer/steel pair to make a polymer gear. Based on the survey of the semi-finished engineering polymer distributors and producers we selected the top five engineering polymers used for gears on the European market to investigate the wear with real elements. The second part gives a summary about the wear testing of polymer spur gears mating with steel gears under abrasive condition. At the end of the paper the evaluation of the measured results and a short conclusion can be found.

Keywords: engineering polymers, spur gears, abrasive wear

1. Used Materials

The properties of the investigated polymers are in the Table 1.

Table 1. Properties of investigated polymers

Polymer	Elongation at rupture A (%)	Young modulus E (MPa)	Rockwell M hardness	Tensile strength R_m (MPa)
PA6G-Mg catalytic	40	3000	86	85
Pa6G-Na catalytic	25	3300	88	80
PA66GF-30	7	5200	98	185
POM-C	30	3000	86	70
PETP/PTFE (TX)	8	3200	94	75

Reference (mating) gear material was S355 structural steel with Ra 2,5 μm.

2. Test System

The testing consists of three main units (fig.1.): two electrical engines with the gear mounted on the shafts and the abrasive dosing unit. One electrical engine is used for driving the test and the other for controlling the break torque.

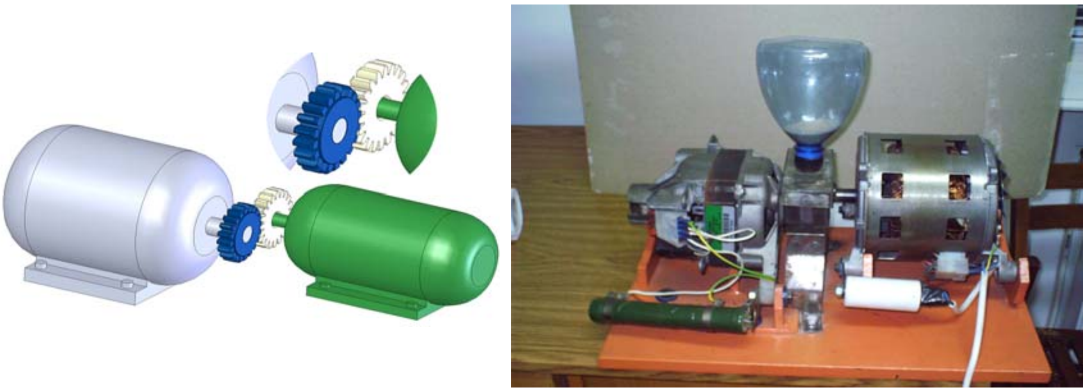


Fig.1. Abrasive testing with spur gears

Test condition

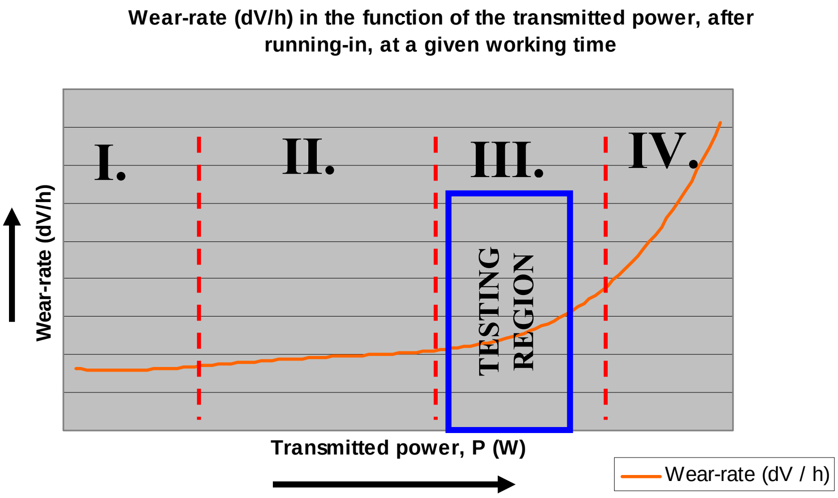
- abrasive media: siliceous sand (fig.2.);
- particle size : < 200 μm (two times screening, first gap clearance 500 μm, second 200 μm);
- driving time in abrasive : 60 minutes/gear pair;
- temperature : + 22 ºC;
- for each measurement a new steel gear was used;
- the sand could flow out from the sandholder via the outlet port with dia Ø1,5 mm at central position above the rotating gears (flow-speed 10 ml./min);
- the classified sand was used only once for measurements, the contaminating polymer and metal particles were observed after the test;
- at the beginning of the test a ten-minute long running-in period was applied without abrasive particles, after this the 60 minutes normal test followed;
- gear weight was determined by “Balanta Sibiu” analytic balance, with accuracy 0,1 mg.;
- multi-teeth measure by a gear tooth micrometer with accuracy 0,01 mm;
- siliceous sand having plastic and steel particles was observed by a “Zeiss Amplival Universal” microscope (magnification 40X), teeth surfaces by a “Zeiss Binocular” microscope (magnification 5X);
- after the measurements the abrasive medium was mixed with glycerol and placed onto the glass slip of the microscope for the evaluation.

Fig.2. Tested polymer gears with the abrasive material

The load level during the measurements was set above (fig.3.) the generally accepted normal load level according to the Lewis formula.

The well-known Lewis-formula gives information about the possible transmitted power in a given construction and operating condition based on the mechanical properties of the bulk material of the gear and focuses on the fatigue stress-limit of the root of the tooth. This mechanical approach does not take the surface frictional and wear load-carrying capacity into account and in the literature there are no information about the connection between the elevated mechanical load and the surface tribology.

It is very important to get to know the wear behaviour during slight overload due to the stochastic change of operating condition from the point of engineering design and safety reasons as well.



I. Technically negligible load
II. Optimal load level based ont he Lewis load-carrying capacity
III. Sligth overload
IV. Strong overload

Fig.3. Testing load level

3. Results

Fig.4. shows the microscopic view of the used siliceous sand. The steel particles can be separated by magnet for further evaluation of the wear process. Fig.5. gives a view about the worn gear teeth surfaces.

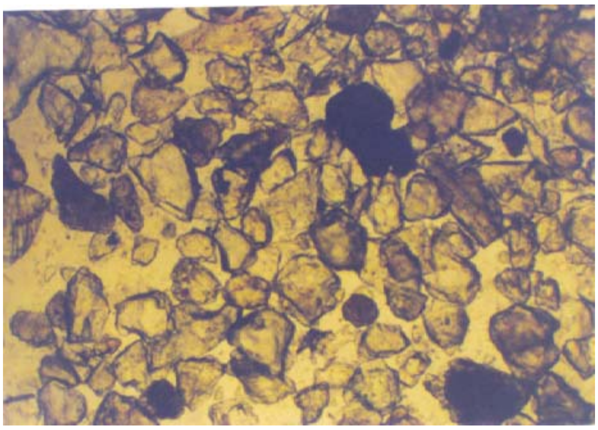


Fig.4. Abrasive sand with PA6-Mg polymer and steel particles after testing. (Magnification 40X)

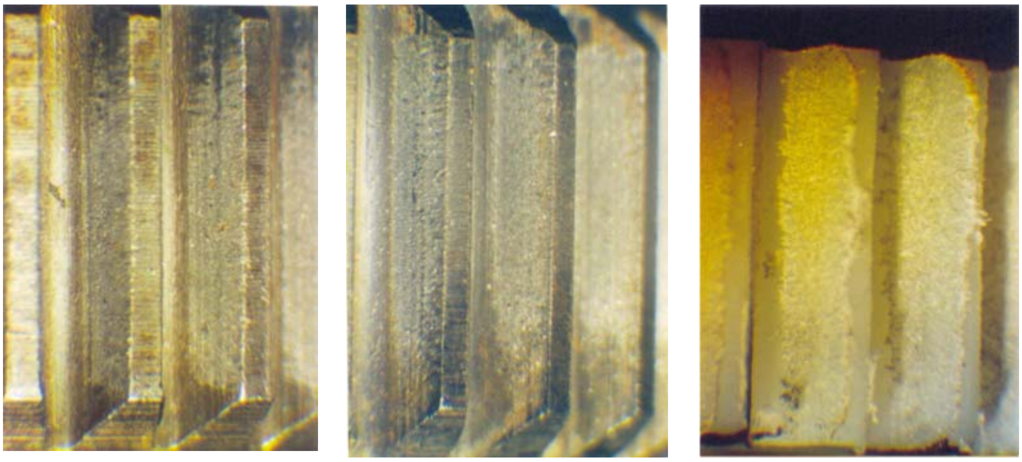


Fig. 5. Worn surfaces of POM C, PETP/PTFE and PA6-Mg

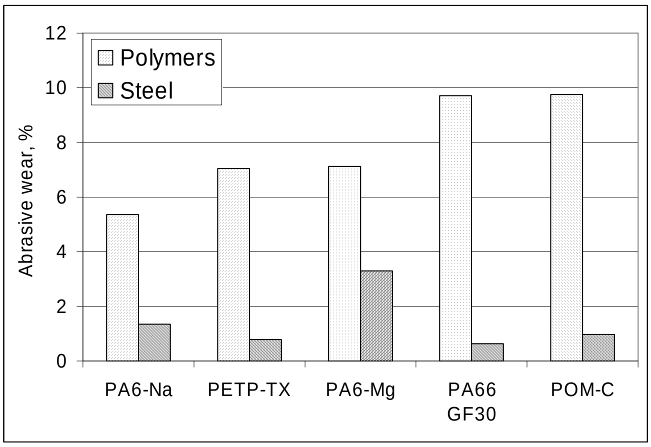


Fig. 6. Wear of polymer/steel tooth gears running without lubrication in abrasive media

It can be seen (fig.6.) that at slightly elevated mechanical load level the different cast polyamides performed well and the PETP/PTFE composite also gave good result. The glass-fibre reinforcement of extruded PA66 does not improve the wear resistance even together with the POM C showed the worst wear values.

Comparing these results with the formerly clarified abrasive wear ranking of these materials under normal load condition, it can be found that the PA6-Mg having high strain capacity and toughness increased the wear of the mating steel gear under elevated load level. This phenomenon may due to the more intense particle embedding ability of the polymer surface.

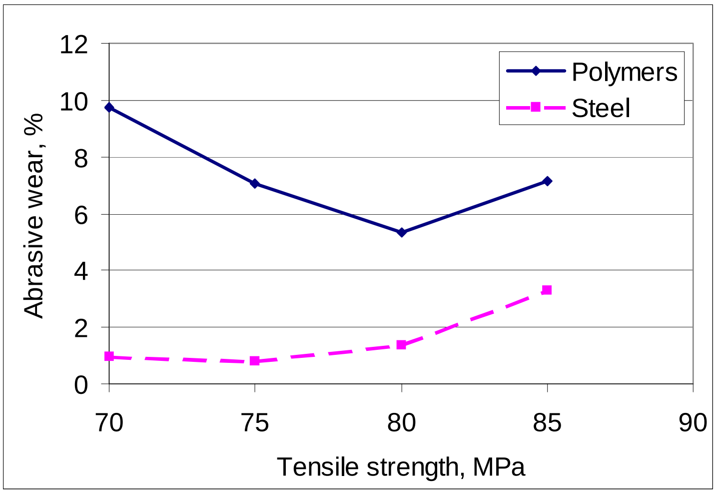


Fig. 7. Wear of polymer/steel tooth gears running without lubrication in abrasive media

During the evaluation of the test results the connection between the wear intensity and the mechanical properties of polymers were searched. As an example the fig. 7. shows the connection between the wear of polymer/steel gears and the tensile strength of polymers. Similar connections and different tendencies were plotted between the wear and the elongation at break-, hardness-, E modulus. The result of glass fiber reinforced polyamide is omitted from this evaluation (fig.7). Further results will be published elsewhere.

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