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FURTHER RESEARCH OF ABRASIVE WEAR BEHAVIOUR OF ENGINEERING POLYMERS

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***Abstract**: To improve the abrasive wear behaviour of a certain tribo system - modifying the system -, there are more keys e.g. replacing the metal surface with a plastic one. If in a given tribo system the engineering plastic part can be acceptable from other engineering points (e.g. strength, life period and fatigue) than the proper plastic selection may improve the abrasive wear performance of the system. The proper plastic material selection is considered as a keyword, because each tribological system is different. Taking these into account, first, we have carried out some simply laboratory test have already been published. Following that we designed a real machine element test systems applying different plastic/metal gear pairs running in abrasive media. The conclusion of the systems and the comparison of the systems were published in different journals and a PhD thesis work was written.*

But to clarify the real plastic material behaviour in case of abrasive particles we had to design a further test system, where the sliding plastic surface always act on a pure abrasive contact surface, which is not covered with transfer layer or third body particles. So, the sliding path to run is always clear. Some mechanical properties of the tested materials were measured at the Hungarian Institute of Agricultural Engineering and tribotesting was carried out at SZIU and UNBM. (OTKA T42511, NI 62729, INNOCSEKK, GVOP 3.3.)
***Keywords:** engineering polymers, abrasive wear*

1. USED MATERIALS

Beside some typical engineering polymers we focused on the different polyamide versions (table 1.) regarding the large number of real applications of theses materials in abrasive engineering solutions.

Table 1.

PA 6G-H Mg catalitc cast polyamide 6	*PA 66E* Extruded PA 66	*PA 6GMo* Cast PA 6 + MoS_2	*PA 6GOL* Cast PA 6 + oil
PA 66GF30 Pa 66 + 30% glass fibre	*POM C*	*PETP*	*PETP TX* PETP + PTFE

2. PREPARATION OF THE TEST SPECIMENS

The test specimens were machined out from semifinished material forms. The final dimension was:

Ø8x15 mm

3. DEVELOPED TESTRIG

The main units of the equipment (Figure 1.) are as follows: the table (1.), the abrasive cloth (2), the elements of the drive mechanism (3), the loading structure (4), and the measurement and data collection unit (5).

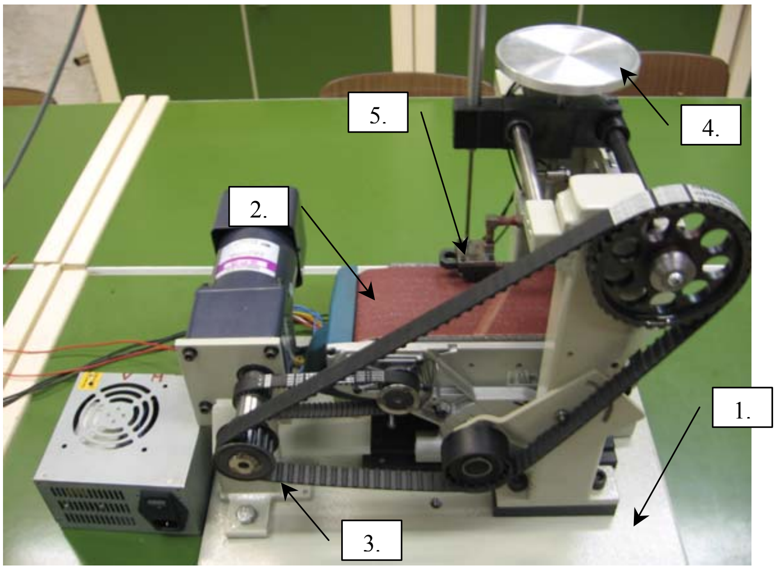

Fig. 1. New testrig

The abrasive cloth is an abrasive paper of the type P60 KK504X NEO fastened to the drum of the grinding machine. The subsequent, planned measurements will be performed by the application of an abrasive cloth of a different surface roughness.

The machine is fastened with its processing surface facing upward, the abrasive plane is parallel with the base surface of the equipment.

The steady, straight-line motion of the cloth is coupled with a lateral feed motion of the sample piece, thus it does not pass over the same abrasive surface twice but it always contacts a new abrasive element. Due to the exact adjustment and regulation of the speed of the abrasive cloth (peripheral speed of the driven cylinder), a separate electric motor is responsible for the drive mechanism. Apart from driving the abrasive cloth, the motor also directs the transverse movement of the sample piece (in relation to the cloth). The coordinated relationship of movements is possible due to the pre-calculated transfer ratios. The drive mechanism consists of ribbed belts.

The load structure forms a single unit with the sample unit grip head traveling on a threaded spindle performing the feed motion. The grip head is located at the bottom of the load structure. The test piece has a cylindrical shape one front surface of which is pressed to the cloth. The diameter of the cylinder is 8 mm and its length is 15 mm. It is important to fasten the tested sample piece in the grip head without the possibility of any movement and also to prevent any substantial deformation because it can influence measurement results. The grip head has strain gauges which make possible the measurement of forces exerted on the test piece during the test. The gauges are connected in a Wheatstone bridge.

The input parameters of the electronic measurement system are as follows:

t –time (s)

F_x – abrasion friction resistance calculated from the movement of the cloth (N)

F_y –abrasion friction resistance calculated from the lateral feed motion of the test piece (N)

F_z –load value in the normal direction (N)

S_{zv} –displacement from the abrasion of the sample piece. (mm)

4. MEASUREMENT PROCESS

we have performed three measurements on one polymer type each, corresponding to the load level values, using loads of 5, 10 and 20 N, respectively. The resting surface pressure can be calculated using the following formula:

$$\sigma = \frac{F}{A} = \frac{F_t}{\frac{d^2 \cdot \pi}{4}}$$

5. EVALUATION OF WEAR

The k value representing wear can be calculated as a quotient of the mass difference of the test piece and the friction path traveled.

$$k = \frac{\Delta m}{s} \quad \left[\frac{mg}{m} \right]$$

After dividing the result [mg/m] by the load force [N], the value of the specific abrasion wear is obtained. It has a reference to the system because it takes into consideration the normal load of the abrasive system.

$$k_f = \frac{\Delta m}{s \cdot F} \quad \left[\frac{mg}{m \cdot N}\right]$$

This figure shows how many mg of abrasive loss is suffered by the test piece used in the system as a result of 1 m of abrasive path and 1 N of load force.

The general specific abrasive wear can be calculated by the following formula:

$$k_{fá} = \frac{\Delta m}{s \cdot \frac{F_t}{A}} = \frac{\Delta m}{s \cdot p} \quad \left[\frac{mg}{m \cdot \frac{N}{m^2}} = \frac{mg \cdot m}{N}\right]$$

The fig. 2 shows the wear losses.

It is instructive to evaluate the results of force and abrasion measurements as a function of time (proportional to the abrasive path) (Figure 3. and 4). We have approximated the values of the abrasive curve by a linear polynomial. By analyzing the equation of the straight line, we obtain

$$y = A \cdot x + b$$

where A: – the slope of the straight line of wear (change of vertical displacement (mm)), a characteristic figure concerning the degree of abrasion speed.

By comparing the a values, the abrasion relationships of individual polymers can be compared.

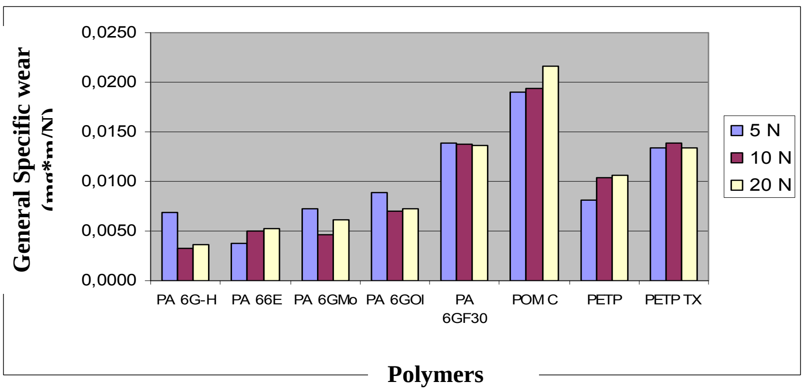

Fig. 2. General specific abrasive wear

Table 2. Linear equations of abrasive friction forces in the function of sliding distance under 20 N.

Table 2.	
	Approximated equations of friction forces
PA 6G-H	0,000251x + 19,109178
PA 66E	0,000113x + 20,589989
PA 6GMo	0,000113x + 20,589989
PA 6GOL	-0,000048x + 18,730922
PA 6GF30	0,000129x + 18,506395
POM C	0,000155x + 20,241552
PETP	-0,020815x + 19,415361
PETP TX	0,000135x + 19,933754

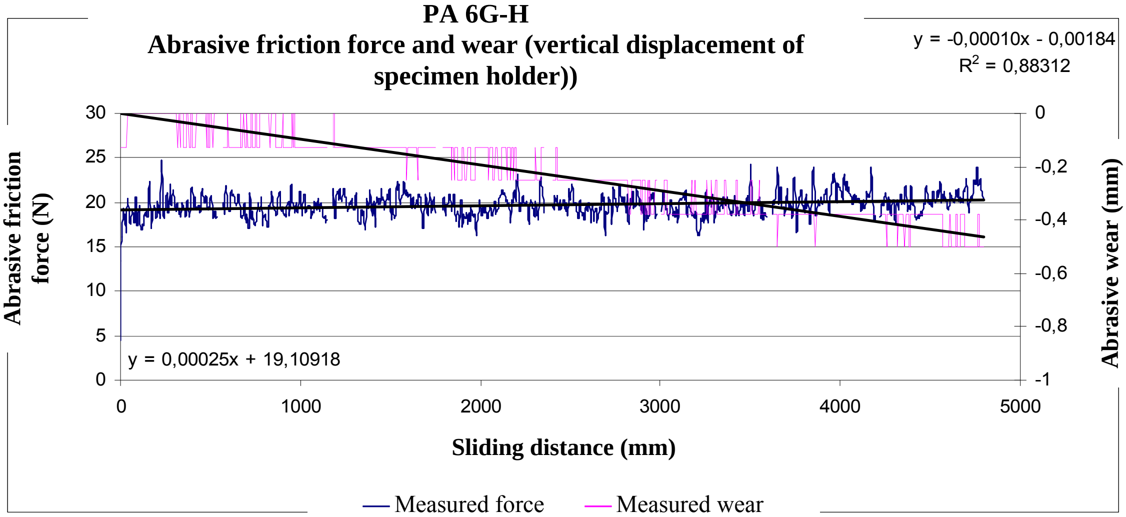

Fig. 3. PA 6G-H abrasive friction force (N) and wear (mm)

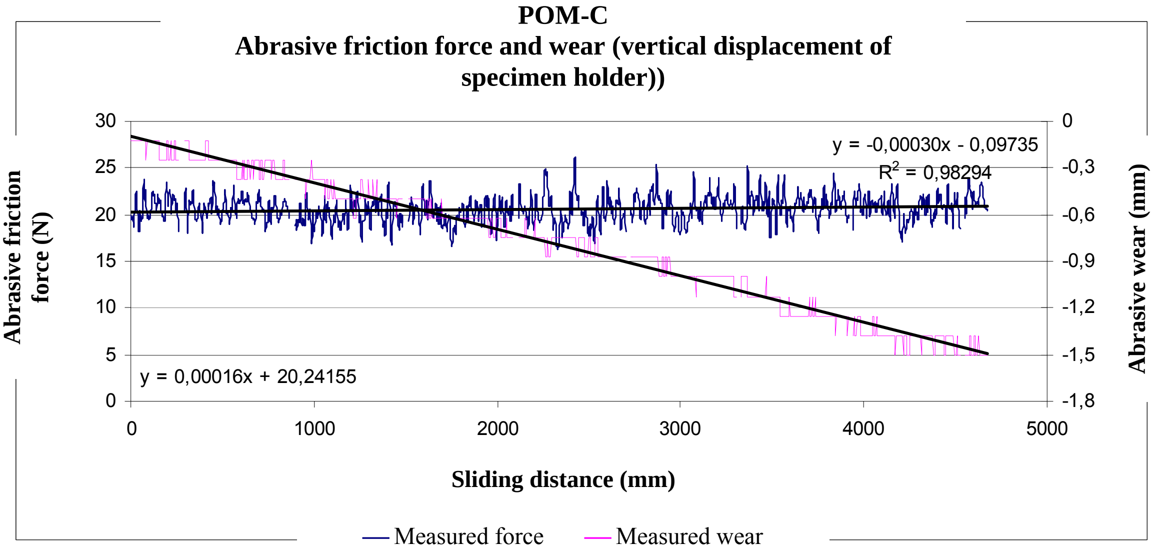

Fig. 4. POM-C abrasive friction force (N) and wear (mm)

6. Summary

- Using the new testing equipment – modified "pin-on-cylinder" measurement principle – the abrasive process can be studied along a longer friction path and by studying a more diverse set of information as opposed to the traditional "pin-on-cylinder" measurements.
- The previous statements published earlier in literature by Ratner proved to be conditionally true (i. e.: linear abrasion dynamics, - the decisive role of tenaciousness and breaking expansion). They have proven to be true for natural polymers but the mathematical relationships can be influenced by the abrasion circumstances and they are not true for all composites.
- In the linear abrasive dynamic region, the measurement results can be used to define the "specific micro cutting resistance" of individual polymers. (Table 3.)

$$c = \frac{F_{átl}}{A_0}$$

Table 3. specific micro cutting resistance (MPa)

PA 6G-H	0,279	**PA 66 GF30**	0,273
	0,379		0,376
	0,614		0,599
PA 66E	0,278	**POM C**	0,274
	0,394		0,395
	0,603		0,611
PA 6GMo	0,277	**PETP**	0,275
	0,379		0,383
	0,592		0,620
PA 6GOL	0,309	**PETP TX**	0,290
	0,441		0,402
	0,690		0,596

- Based on the evaluation of the diagrams so far, it can be established that the tenacious but highly solid natural, cast polyamide 6 exhibited the smallest degree of wear and the POM copolymer wore of most rapidly..
- The PTFE (Teflon) additive increasing tenacity did not result in a decrease of wear in PETP (material marked with "PETP TX"), but it wore much more than rigid, natural PETP. Thus, the Ratner theory cannot be applied for this composite version – when comparing materials of identical basic matrices.

- Based on further measurements and results, the speed of abrasion wear and specific abrasion wear can be analyzed as a function of material properties which may deliver further new scientific results in the future.

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