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EXPERIMENTAL RESEARCH ABOUT TOOTHED GEARS MADE OF PLASTIC MATERIALS UNDER ADHESIVE AND ABRASIVE CONDITIONS

Otto-Paul Eberst[1] Robert Keresztes[2] Elena-Angela Pop[3] Sever Pop[4]
[1,3]PhD .Eng., [2,4]Eng.
[1,3]North University of Baia Mare, [2]Szent István University Gödöllő, [4]PRONED CONTROL Baia Mare

Abstract: *In this work are presented the results of experimental research regarding the wearing of cylindrical toothed gears with straight teeth and with one gear made of steel and the other made of different high performance plastic materials. The wearing are studied under slightly overloaded conditions both for dry friction (purely adhesive) and for friction realized with abrasive quartz (siliceous sand) particles.*

The conclusions presented here are useful at chooseing the mostly proper plastic material for toothed gears and for frictions existing under some specific technical condition.

Key words: *plastic/steel toothed wheels, slight overload, adhesive and abrasive wearing.*

1. INTRODUCTION

The technical plastic materials have a series of advantageous physical-mechanical properties which made possible their usage at different gearing types.

The usage of these are recommended where – among maching the conditions for mechanical resistance – are important the following aspects, too:

- fine and silent functioning,
- resistance to corrosion and to chemical agents,
- resistance to usage, shocks and vibrations,
- reduced weight.

Chooseing the mostly proper type of plastic material for certain working condition must not be done exclusively based on mechanical and termic properties, but keeping at sight some tribological aspects, specific of these polymers.

2. PLASTIC MATERIALS AND STALLS USED AT EXPERIMENTS

For tests it was used five types of plastic materials which are recommended by their producers for gearing transmissions. The main physical and mechanical properties of these materials are presented in table 1.

Tabel 1. Properties of materials used at tests

Material type / Properties	U.M.	PA6-Mg	PA6-Na	POM-C	PA66 GF 30	PETP Tx
Colour	-	white-yellow	white-yellow	white	black	grey
Density	g/cm^3	1,17	1,17	1,41	1,29	1,44
Tensile stress at yield	N/mm^2	85	80	70	-	75
Brakeing resistance	N/mm^2	-	-	-	185	-
Modulus of elasticity	N/mm^2	3000	3300	3000	5200	3200
Elongation at brake	%	40	25	30	7	8
Rockwell hardness	-	M86	M88	M86	M98	M94
Linear dilatation factor	$m/m{\cdot}K{\cdot}10^{-6}$	90	90	110	45	65
Minimal allowable service temperature	^0C	-30	-40	-50	-20	-20
Maximal allowable service temperature	^0C	100	85	115	120	115
Melting point	^0C	220	220	165	255	255
Humidity absorbtion	%	2,6	2,6	0,2	2,4	0,25

For tests was made a system which allowed testing under slighty overloaded conditions of the metallic gears and the plastic gears. The system has been created to allow testing under abrasive friction, too by accommodating a dosage system for abrasive particles and carcassing of toothed gears. The main components of the following figure 1 are: foot plate; 2.entrapment electrical engine; 3.brake electrical engine; 4.steel toothed gear; 5. plastic toothed gear; 6. adjustable electrical resistance.

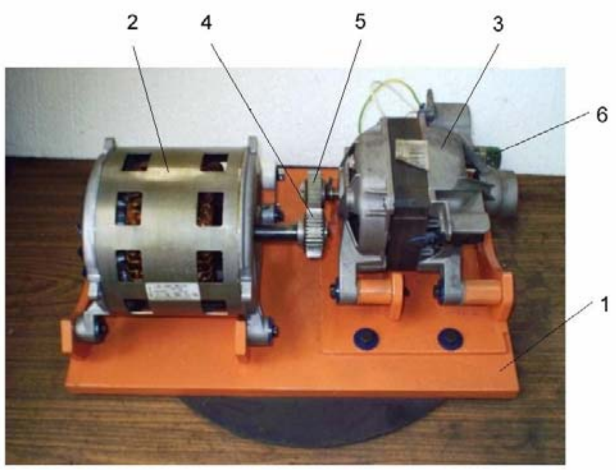

Fig.1. System for toothed gears testing

The steel and plastic made toothed gears we used are illustrated in figures 2 and 3.

3. UNFOLDING THE EXPERIMENTS

For resulting measurable wear on toothed gears, the gearings were overloaded with bigger charges then the admittable ones resulting from materials hardness calculations (the charge was 6,1 N·m compareing to the admissible 3,6 N·m, calculated with Lewis' relation for the weakest plastic material; rotation speed n = 1300 rotation / min.). Duration of tries for each plastic/steel gearing was 70 hours under adhesive conditions, respectively 60 minutes under abrasive particles wearing (quartz with a 200 µm granulation). After ending the tests, there were determined the mass wearing percentages both at steel toothed gears and plastic toothed gears, with the following relation:

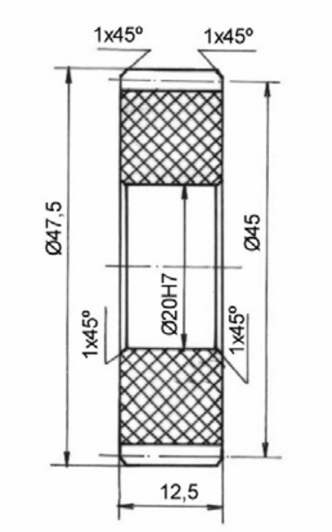

Fig. 2. Plastic toothed gear.

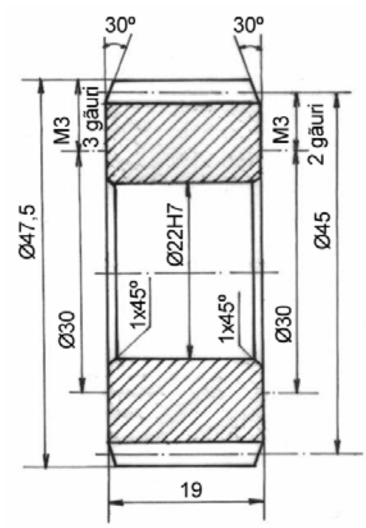

Fig. 3. Steel toothed gear.

$$u = \frac{m_i - m_f}{m_d} \cdot 100\% \qquad (1)$$

where:

u – percentual mass wearing (usage);

m_i- initial mass of the toothed gears (new gears);

m_f- final mass of the toothed gears (used gears);

The final mass m_f was determined after drying the toothed gears with a gel exicator (due to absorbtion of humidity !)

m_d- mass of the denting zone of the gears (between head diameter and leg diameter of the toothed gears). It has been considered that only this zone is exposed to the usage process.

At tests under adhesive conditions were determined the vibration levels of the gearings with both new and used gears.

4. THE OBTAINED RESULTS

By measureing the vibration levels resulted the diagram presented in figure 4.

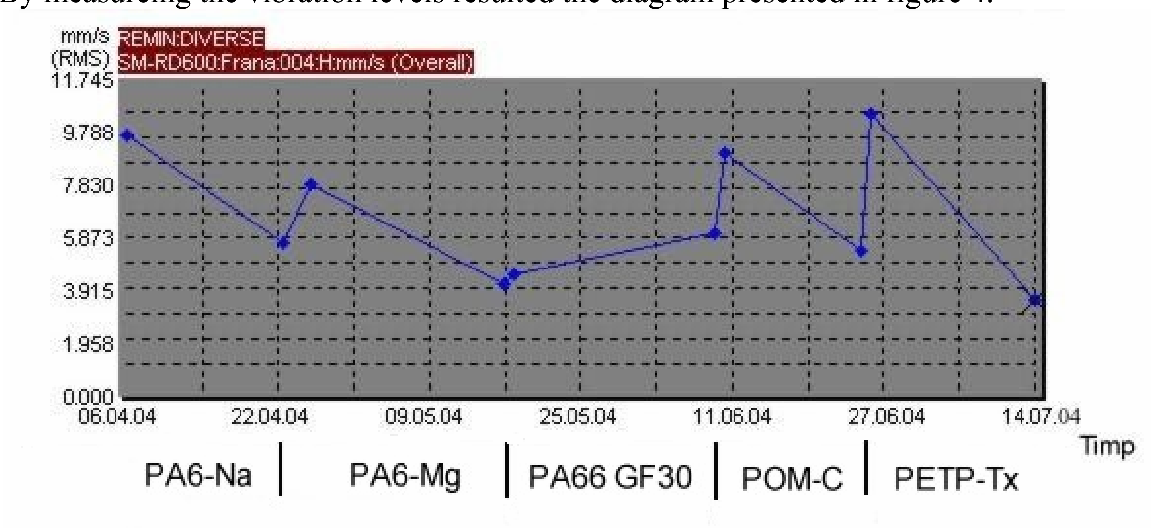

Fig. 4. Vibration level tendencies diagram.

It is noted that gearings vibrations (measured in two directions) are decreaseing at the same time with the evolution of the component toothed gears usage process. The exception is given by the gearing with one toothed gear made from the PA 66 GF 30 material (polyamid reinforced with glass fibre) where the vibration level had increased.

After gravimetric measurements for adhesive friction resulted the diagram presented in figure 5.

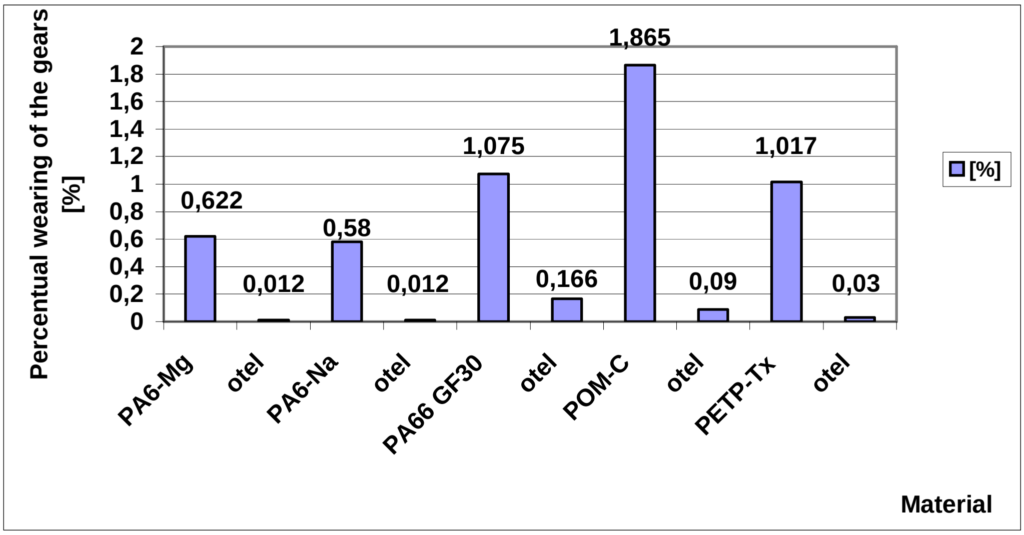

Fig. 5. Percentual mass wearing of the denting at toothed gears made from plastic and those made from concerted steel at dry friction after 70 hours functioning

The two polyamid types PA6 (PA6-Na and PA6-Mg) have the smallest wearing, followed by the PA66 GF30 and PETR-Tx (polietilenterephtalat). The worst wearing occurs at the POM-C (poliacetal) toothed gear.

The steel toothed gears wearing are unsignificant compared with the wearing of the plastic toothed gears.

After the gravimetric measurements for friction with quartz abrasive particles, it resulted the diagram presented in figure 6.

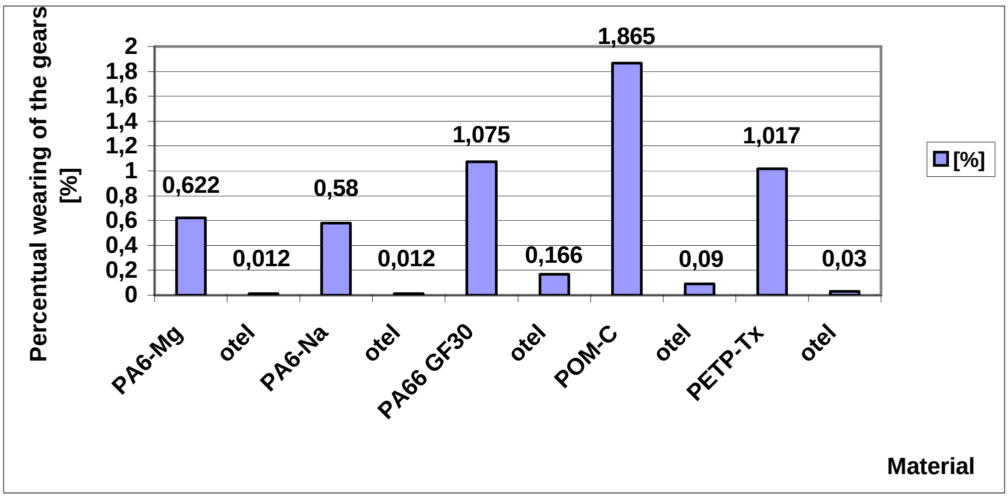

Fig. 6. Percentual mass wearing of the denting at toothed gears made from plastic and those made from concerted steel at dry friction after 60 minutes functioning

The two polyamid types PA6-Na and PA6-Mg resist the best under abrasive conditions, too followed by PETP-Tx, PA66 GF30 and POM-C.

If we analyze the wearing of concerted steel gears we can see the smallest wearing happening at the metal gear when we use the toughest plastic material (PA66 GF30), meanwhile the softest material (PA6-Mg) inflicts the greatest wearing upon the metal gear.

Under abrasive conditions the wearing of steel gears are already significant: in some cases the mass wearing of steel gear is bigger than the the mass wearing of concerted plastic gear (by example, at the PA6-Na and PA6-Mg).

5. CONCLUSIONS

Based on the enterprised experimental research and keeping in mind the results of other researches (which were not presented in this work) we can formulate the following conclusions regarding the utilization possibilities of plastic materials tried at gearing transmissions:

PA6-Mg polyamid with magnesium catalysis

- it has a good wear resistance, especially under dry friction; in abrasive medium has moderate wear, but causes great wear in case of concerted metal gears;
- it can be used under heavy functioning conditions (shocks, vibrations, dust, incomplete oiling) and at the big dimension gearings, uncarcassed;
- it is not recommended to be used in wet medium, for immersed gears or for high precision gears;
- available semi-manufactured items: bars with diameters between 40 and 500 mm;
- usable with some restrictions in the food industry;
- acquisition price is the most advantageous.

PA6-Na polyamid with natrium catalysis

- it has the best resistance at wearing, both in adhesive and abrasive mediums. Also, it has good results at experiments on standardized probation items;
- it can be used in same areas as the PA6-Mg polyamid having the same using restrictions, too;
- available semi-manufactured items: bars with diameters between 10 and 500 mm; plates between g1 and g 100 mm; bars until 600 mm external diameter;
- acquisition price is with 25 % bigger than PA6-Mg.

PA66 GF30 polyamid reinforced with glass fibre

- it has a satisfactory wearing resistance under adhesive friction and a poor one under abrasive conditions;
- it is an unizotropic material and its behavior could be influenced by the orientation of the glass fiber casing;
- can be used at gearings working under higher temperatures which regards better dimensional stability;
- it is not recommended to be used at uncarcassed gearings working with big shocks and vibrations;
- it is recommended oiling the gears made of PA66 GF30 for diminishing the adhesive and abrasive wearing values;
- available semi-manufactured items: bars with diameters between 10 and 200 mm;
- cannot be used in food industry;
- protects the concerted steel gear under abrasive conditions;
- acquisition price is almost double compared with PA6-Mg.

POM-C poliacetal-copolymer

- it has the worst wearing resistance among the analyzed materials both in adhesive friction and abrasive conditions;
- this material does not respect the same tribological behavior laws as the PA6 or the PETP – Tx due to its different matrixl structure;
- can be used for gears transmitting low charges but regarding high precision and dimensional stability;
- can be used without any restrictions in the food and pharmaceutical industries (without oiling!);
- could be used for immersed toothed gear works (wet environment) but fails to resist properly at bad weather;
- available semi-manufactured items: bars with diameters between 10 and 320 mm; bars with external diameter of maximum 350 mm, plates between g 1 and g 100 mm;
- acquisition price is with 50% bigger compared with PA6-Mg.

PETP-Tx

- it has good resistance in abrasive environment but only satisfactory in adhesive friction;
- can be used at gears working with relatively high temperatures which regards also good precision and dimensional stability;
- it is usable in food and pharmaceutical industries even in case of toothed gears working in wet environment (immersion);
- could be used at big, uncarcassed gears too working in difficult conditions (shocks, vibrations, abrasive dust);
- the wearing of toothed gears made out of PETP-Tx can be significantly reduced by oiling;
- protects concerted steel gears especially under abrasive conditions;
- available semi-manufactured items: bars with diameters between 10 and 150 mm; bars with external diameter of maximum 200 mm, plates between g 10 and g 80 mm;
- acquisition price is with 70% bigger compared with PA6-Mg.

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