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[1.]Cristian MUNTENIȚĂ, [1,2.]Marius BODOR,
[1.]C. UNGUREANU, [1.]Vasile BRIA, [1,2.]Adrian CÎRCIUMARU, [1,2.]Iulia GRAUR

TRIBOLOGICAL PROPERTIES OF ULTRA-SONICATED ALKALINE ION DOPED EPOXY

[1.]"Dunărea de Jos" University, Galati, ROMÂNIA,
[2.]Diagnose and Measurement Group, Galați, ROMÂNIA

ABSTRACT: In this paper, we describe the influence of ultra-sound exposure time and tribological properties regarding formation of composites with two different salts doped epoxy resin. Potassium dichromate and Sodium dichromate were choosen due to their flexible way of use and the novelty of their usage to form epoxy composites. The time of ultra-sound exposure was, each time, of 1, 2, 3, 4, and 5 minutes. The doping method had been developed as part as research activity under the Project POSCCE 12P01.024/CD111. All the presented experiments and results are performed and obtained at Polymer Composites Laboratory of Dunărea de Jos University of Galați.
Keywords: tribology of polymeric materials, ultra-sound, alkaline ion, epoxy

1. INTRODUCTION

Polymers play an important part in materials and mechanical engineering, not just for their ease in manufacturing and low unit cost, but also for their potentially excellent tribology performance in engineered forms [1]. Bhushan [2] described tribology as the science and technology of interacting surfaces in relative motion and of related subjects and practices as well as supporting activities that should reduce costs resulting from friction and wear [3-4]. Tribology is the art of applying operational analysis to problems of great economic significance, namely, reliability, maintenance, and wear of technical equipment, ranging from spacecraft to household appliances [5]. Relatively much research has been conducted on the effect of reinforcing fibers and tribological properties [6] but the field of the ultra-sonicated composite materials together with salts doped epoxy resin has not been studied enough. In comparison with the widely used filler content [7-8] adding salts and ultra-sound exposure into the epoxy matrix may have different effects on the tribology properties of the epoxy composite. Requests on studying tribological behavior of polymers and their composites increased greatly. Various researchers have studied [9-10] friction and wear polyester with the addition of various compounds, such as graphite, AlO_3, PbO, CuS, CuO, PbO, PBS, TiO_2, ZrO, and some metal powders. There is relatively little information on friction and wear behavior of filled thermoset polymers. A preliminary investigation into certain tribological aspects of epoxy composites was carried out in [11] and show that adding inorganic fillers tough irregular shapes can have a harmful effect on the wear characteristics of the composite. Wear behavior of spherical silica submicron particles in epoxy polymer composites is discussed in [12]. Spherical silica particles can improve the wear resistance of the epoxy matrix, even if the content of the additive was relatively low. It was found that material with a smaller additive was effective to improve the wear resistance. There are also important effects of reinforcements or modifying agents on the tribological and wear properties of composites [13-15]. The preceding analysis of the existing literature shows that the influence of ultra-sound exposure time on alkaline ions doped epoxy resin was not enough investigated.

2. TECHNICAL REQUIREMENTS

Crystals of Potassium dichromate and Sodium dichromate were initially subjected to a process of mechanical grinding and then were dissolved in nitrodiluant. The obtained solutions were mixed in epoxy system. Finally to obtain a resin-containing compound with ions originating from dissociation of the salts. The amounts of salts had been computed such as the doping levels to be of 1 alkaline ion at 5000 bisfenol A molecules and with decrements of 1000 up until 1 alkaline ion to 1000 bisfenol A molecules and with decrements of 100 from 1/500 to 1/100 alkaline ion/bisfenol A molecules [16].Ultra-sound sonotrode for experiments is 3 MS3 Ø 3 mm diameter Micro Type with acoustic power of 460 W / cm² and maximum amplitude of 180 μm (Figure 1). Tribological characterization was performed using UMT-2 (CETR®, USA) universal tribometer on tribological test module dedicated to block-on-ring tests that allows setting and viewing of control and measured parameters: test rotational speed, loading force, friction and wear coefficients. The block is made of the material to be analyzed and is secured in the support of the machine, positioned perpendicularly to the ring (Figure 2).

Figure 1: Ultrasonic Processor UP100H during epoxy treatment

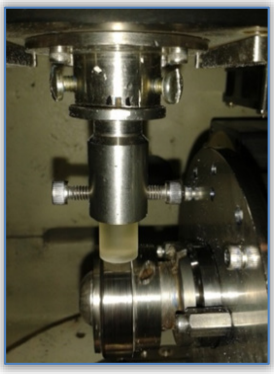

Figure 2: Block-on-ring module

Friction can be defined as the tangential resistance force in the relative motion of two surfaces in contact and has the following formula [4]:

$$F=\mu N \quad (1)$$

where N is the normal force and μ represents friction.

Tribological tests for all types of composite were performed under dry conditions on a ring made of steel with outside diameter of 35 mm. The length was set at 1650 meters and speed test between 0.46 [m/s] and 1.83 [m/s]. Using UMT-2 (CETR®, USA) universal tribometer testing parameters have been established as follows:

a. Speed testing of 0.46 [m / s], load of 20N, distance 1650 meters.
b. Speed testing of 0.92 [m / s], load of 10N, distance of 1650 meters.
c. Speed testing of 1.83 [m / s], load of 5N, distance of 1650 meters.

3. RESULTS AND DISCUSSION

In each representation, three curves are shown. One corresponding to sliding friction coefficient of the analyzed material, one for sliding friction coefficient of epoxy resin and another one for sliding friction coefficient of diluted resin (a- the evolution of sliding friction coefficient graph registered by test machine, b-polynomial trend of friction coefficient and c-linear trend of friction coefficient).

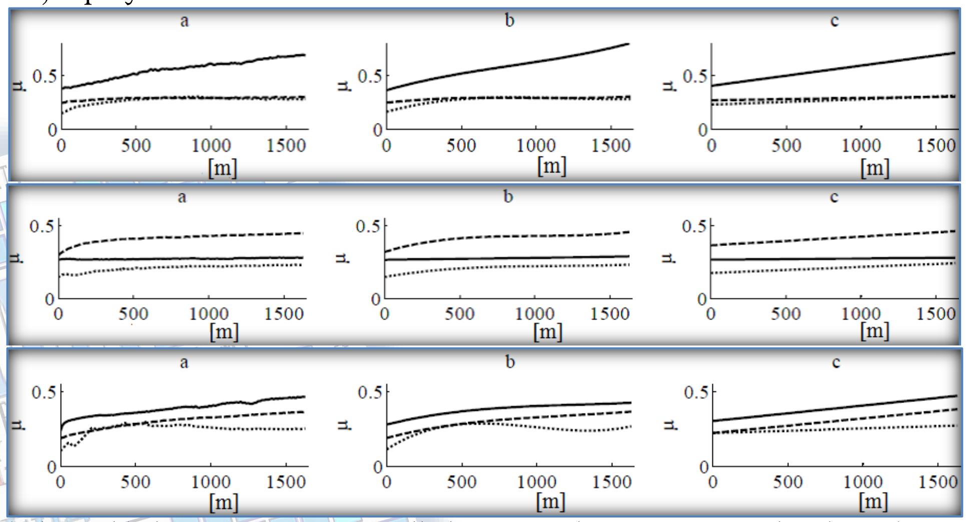

Figure 3: Tribological behavior of Potassium alkaline ion polymer at 400 molecules of bisfenol A for 5N, 10N and 20N load and one minute ultrasonic treatment

As seen from Figure 3 and Figure 4 , tribological behavior of Potassium and Sodium alkaline ion polymer at 400 molecules of bisfenol A and one minute ultrasonic treatment, the friction coefficient under dry friction condition increases to the maximum value for 20N applied load. It should be noted that diluted resin has the weakest tribological behavior.

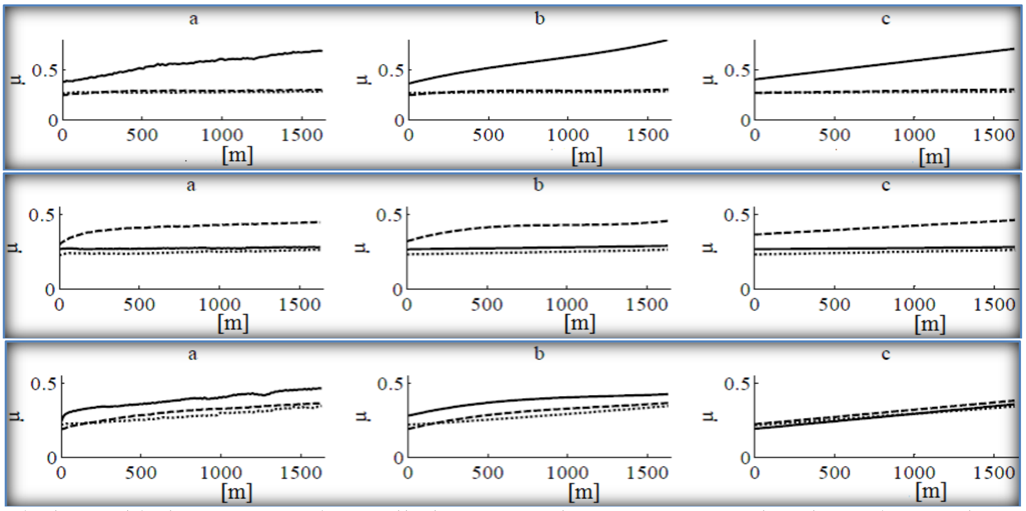

Figure 4: Tribological behavior of Sodium alkaline ion polymer at 400 molecules of bisfenol A for 5N, 10N and 20N load and one-minute ultrasonic treatment

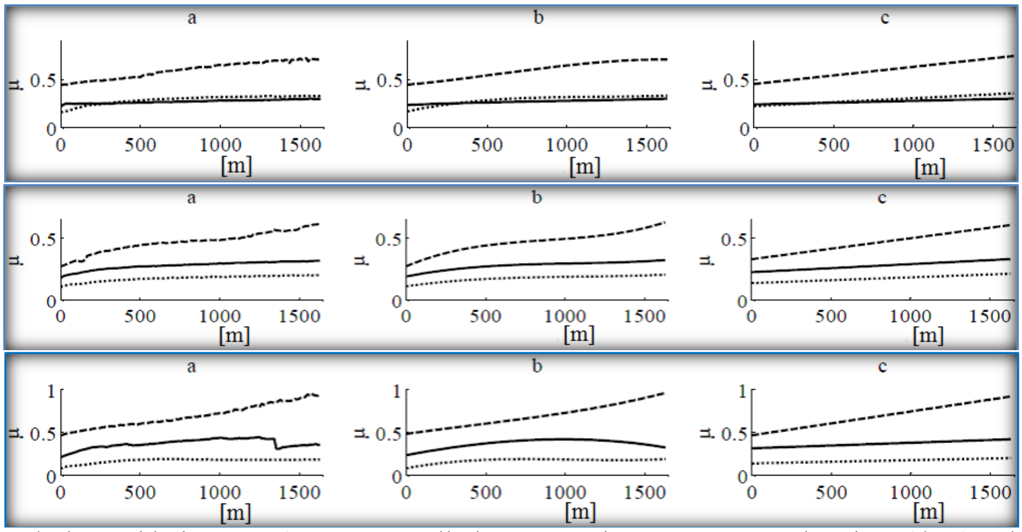

Figure 5: Tribological behavior of Potassium alkaline ion polymer at 400 molecules of bisfenol A for 5N, 10N and 20N load and five minutes ultrasonic treatment

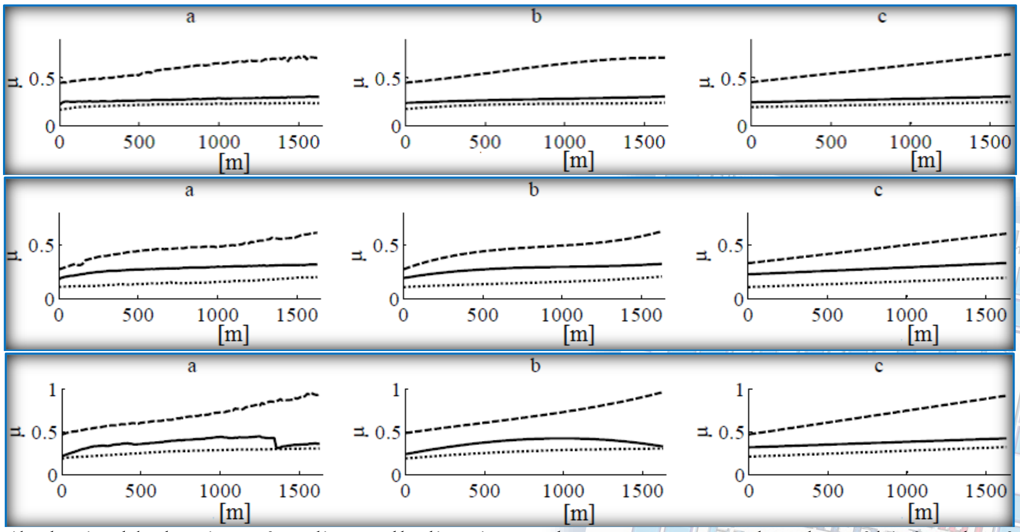

Figure 6: Tribological behavior of Sodium alkaline ion polymer at 400 molecules of bisfenol A for 5N, 10N and 20N load and five minutes ultrasonic treatment

The results in Figure 5 and Figure 6 confirm that when the load increases the doped materials friction coefficient decreases. Be mentioned that this behavior does not depend on the type of salt used as a doping agent. Analysis of thermal field of tribological systems for materials described above leads to the conclusion that local, doped materials shows an increase in the temperature value of 2-5°C, as shown in Figure 7.

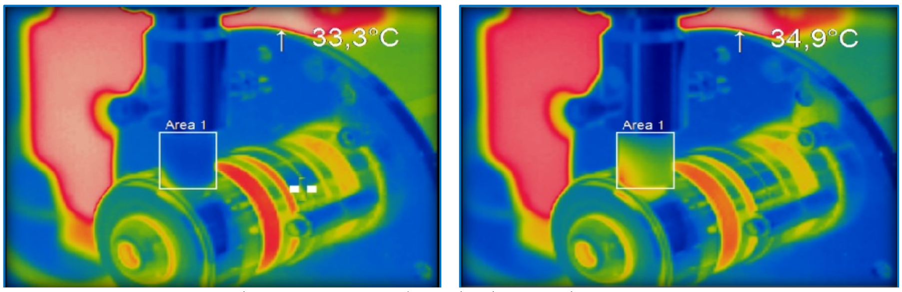

Figure 7: Temperature values measured with thermal imager Optris®Optris® PI 160.

The fact that these doped materials have the best tribological replied must be a consequence of pre-polymer - diluent - salt interaction under ultrasound treatment, affecting the internal structure of materials.

4. CONCLUSIONS

Tribological tests have been designed in such way that the product of the loading force module and speed sliding module to be constant. Coefficients of sliding friction on steel decrease with increasing loading and shows generally the minimum values for tests with loads of 20N. Diluted and exposed to ultrasound resin has generally the weakest tribological behavior. Potassium dichromate and Sodium dichromate salts used for doping improves the tribological behavior of materials. Alkaline materials with one atom at 400 molecules of bisphenol A have a very good tribological behavior.

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References

[1.] K. Friedrich and A.K. Schlarb, Tribology of Polymeric Nanocomposites, 2008.
[2.] B. Bhushan, Principles and Applications ofTribology, John Wiley & Sons, New York, 1999.
[3.] W. Brostow, Kovačević, Vera, D. Vrsaljko and J. Whitworth, Tribology of polymers and polymer-based composites, Journal of Materials Education, Vol. 32, 2010.
[4.] E. Rabinowicz, Friction and Wear of Materials, 2nd ed., Wiley, New York, 1995.
[5.] B. Bhushan, J. N. Israelchvili and U. Landman, Nanotribology: Friction, Wear and Lubrication at the Atomic Scale, Nature 374, 1995.
[6.] K. Friedrich, R. Reinicke and Z. Zhang, Wear of polymer composites, Eng. Tribol. Part J, 216, 2002.
[7.] Q. M. Jia, M. Zheng, C. Z. Xu and H. X. Chen, The mechanical properties and tribological behavior of epoxy resin composites modified by different shape nanofillers, Polym. Adv. Technol. 2006.
[8.] N. K. Myshkin, M.I. Petrokovets and A.V. Kovalev, Tribology of polymers: Adhesion, friction, wear, and mass-transfer, Tribol. Internat. 38, 2005.
[9.] A. Akincia, M. Ozsoyb, M. Firatb, U. Sena, Tribological Behaviors of SiO2 Added Polyester Matrix Thermosetting Composites, Proceedings of the 3rd International Congress APMAS2013, April 24-28, Antalya, Turkey, 2013.
[10.] P.N. Bogdanovich, Deformations and failure of polymer material surface layers during friction. Sov. J. Frict. Wear 3(2), 1982.
[11.] M. Rubenstein, M. Burdekin, Wear assessment of epoxy composites used for machine slideways, Wear, Vol. 55, pp: 131–142, 1979.
[12.] X.S. Xing, R.K.Y. Li, Wear behavior of epoxy matrix composites filled with uniform sized sub-micron spherical silica particles,Wear, Vol. 256, pp: 21–26, 2004.
[13.] M. Campo, A. Jimenez-Suarez, A. Urena, Effect of type, percentage and dispersion method of multi-walled carbon nanotubes on tribological properties of epoxy composites, Wear, Vol. 324-325, 2015, 100 – 108
[14.] J.H. Han, , H. Zhang, P.F. Chu, A. Imani, Z. Zhang, Friction and wear of high electrical conductive carbon nanotube buckypaper/epoxy composites, Composites Science and Technology, Vol. 114, 2015, 1 – 10.
[15.] J.T. Shen, M. Top, Y.T. Pei, , J. Th.M. Hosson, Wear and friction performance of PTFE filled epoxy composites with a high concentration of SiO_2 particles, Wear, Vol. 322-323, 2015, 171 – 180.
[16.] M.Boţan, I. Bosoancă, R. Bosoancă, Iulia Graur, I. Mihalache, M. Bodor, A. Cîrciumaru, Abrasive Wear of Salts Doped Epoxy Composites, Tribological Journal BULTRIB Vol. 5, 2015.