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# FRICTION COEFFICIENT OF POTASSIUM AND SODIUM DICHROMATE DOPED EPOXY

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***Abstract:*** *In this article we describe a less conventional method of ultra-sound exposure and friction coefficient variation regarding formation of composites with two different salts doped epoxy resin at three concentrations. Although the method is easily applied, we have illustrated that the doping method has a good influence on friction coefficient variation for three applied regimes. Introduced into an nitro solvent and then on an epoxy resin, the potassium and sodium dichromate dispersion homogeneity influence extensively the composite's performance. As the ultra-sonication is a very used method to disperse the particles into the polymer matrix, this study is motivated by the desire to identify the ways in which is possible to obtain a composite with a good friction coefficient.*

***Key words:*** *friction coefficient, ultra-sound, epoxy, potassium dichromate, sodium dichromate.*

## 1. Introduction

Polymers and structural composites are used in a variety of applications, which include transport vehicles (cars, aircrafts, ships, and space crafts), sporting goods, civil engineering, and electronics [1].The present article provides an extension and update of others articles [2], [3]. One of the most important stages involved in the production of polymer products, from the synthesis of raw materials to the manufacturing of the finished product, is the polymer material processing. Nowadays, the rapid diffusion of polymeric materials in new markets requires not only the innovation in new technological processes but also the upgrading of existing polymer processing technologies, which allow them to extend in new application fields [4].

The ultra-sonication of epoxy resins constitutes a new research branch and being in continuous development it contributes to the development of polymer materials [5], [6]. Many studies demonstrated that the main role in determing the composites properties is played by the interface fillers particles polymer [7], [8], [9]. For this study the ultra-sonication is considered as a challenge. The aim of the research is to increase the knowledge regarding experimental analysis of tribological loads

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of sodium and potassium dichromate doped epoxy resin for three concentration of the salts.

Friction is the resistance to motion that occurs whenever one solid body is in contact with another solid body [10]. Wear and friction are not material properties, but the answer of a given tribosystem [11]. The non-polymer-on-polymer tribosystems are often applied in various machines and devices. This is probably due to good mechanical and thermal properties of the counter-face rubbing element. The most popular and also practically confirmed as the best tribological combination is steel-on-polymer frictional tribosystem [12]. Very wide possibilities to modify polymeric materials by fillers, lubricants and many other additives [13] give very good perspectives to find polymeric composites that show excellent tribological properties both as matched with non-polymer or with another polymeric component [14], [15]. In comparison with the widely used filler content [16], [17] adding salts and ultra-sound exposure into the epoxy matrix may have different effects on the tribological properties of the epoxy composite.

The key step of the present research and of materials formation was to choose the salts that could be used to dope the resin. The decision regadring the use of potassium and sodium dichromate was imposed by their availability, their properties (with high emphasis on thermal and chemical properties), their flexible way of use and the novelty of their usage to form epoxy composites.

Friction properties of potassium and sodium dichromate doped epoxy, with different proportions and ultra-sound exposure were investigated in three aplied regimes. As a comparison, the friction properties of unfilled epoxy were also evaluated under the identical test conditions.

## 2. Experimental Method

The epoxy system WWA-WWB from *Resoltech* had been used as matrix. The resin contains 75-78% bisfenol A according to the specification and the materials had been formed based on the lowest value such as at a given number of bisfenol A molecules to correspond an alkaline ion. The two salts were solubilized into the solvent and the solution was mixed with the main component of epoxy system. When the dispersion was uniform the conditions for solvent vaporization were set as follows: mechanical stirring at 200rot/min, temperature $70^{o}C$ and continuous ventilation above the pot. The duration for solvent removal is about 150 minutes [3]. After the solvent is removed the alkaline and dichromate ions are remaining into the polymer. The resin-ions mixture was mixed with the required amount of hardener and samples were formed into cylindrical moulds of 11 mm diameter and 200 mm height. For each material six samples were formed. As reference materials epoxy resin and diluted resin had been formed. The diluted resin is the epoxy resin in which the solvent was mixed and then removed.

From the empirical point of view during the research a less conventional method had been used. This method consists on usage of ultra-sound processor UP100H equipped with MS3 sonotrode having 3mm diameter and acoustic power of $460W/cm^2$ (Fig.1) and using 5minutes ultra-sound exposure time and various concentrations of doping salts.

15 materials had been formed. 3 of them are considered as reference materials and they are: **Resin**-the epoxy resin, **RU**-the ultra-sonicated epoxy resin and **RD-** the diluted epoxy resin. The time of ultra-sound exposure was 5 minutes. The amounts of salts had been computed such as the doping levels to be of 1 alkaline ion

at 5000, 400 and 100 bisfenol A molecules.

*Fig. 1. Ultrasonic Processor UP100H during epoxy treatment [2]*

Other materials are:
**PD1, SD1**-1 potassium ion, respectively 1 sodium ion at 5000 bisfenol A molecules; **PD2, SD2-**1 potassium ion respectively 1 sodium ion at 400 bisfenol A molecules; **PD3, SD3** -1 potassium ion respectively 1 sodium ion at 100 bisfenol A molecules; **PU1, SU1** - ultra-sonicated 1 potassium ion respectively 1 sodium ion at 5000 bisfenol A molecules;
**PU2, SU2--** ultra-sonicated 1 potassium ion respectively 1 sodium ion at 400 bisfenol A molecules;
**PU3, SU3** - ultra-sonicated 1 potassium ion respectively 1 sodium at 100 bisfenol A molecules.

As per this study the target was to obtain a uniform dispersion of salty solution into the polymer, as a condition to obtain the pre-polymer solution. That, and as consequence the materials formation, required establishment of components compatibility ï the resin (the two components of the epoxy system) with the nitro-diluent, the salts with the nitro-diluent and the salts and the two components of the epoxy resin. Friction coefficient of modified epoxy matrix was measured using pin-on-disc tribometer TRM 1000 (Wazau®, Germany) (Fig.2) in the Polymer Composites Laboratory of *Dunărea de Jos* University of Gala˝H

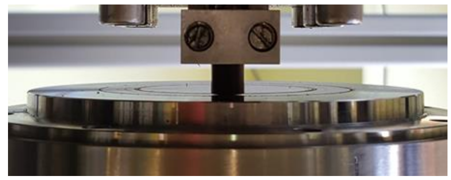

*Fig. 2. Testing device WAZAU Tribometer TRM 1000 pin-on-disc module*

The friction tests were carried out under three different regimes, such as:
**R1** ï 1.2 m/s sliding speed and 50 N normal load,
**R2** - 1.5 m/s sliding speed and 40 N normal load,
**R3** ï 2 m/s sliding speed and 30 N normal load.

The sliding distance was constant for all studied regimes, namely 1000 m. The three regimes were set such as the product sliding speed normal force to be constant and the values are given in the graphs below.

### 3. Results and Discussions

Initial solubility of both salts is controlled by the physical interactions between the modifier and the resin system. This solubilization is not possible. The two salts were solubilized into the solvent and the solution was mixed with the main component of epoxy system. The evolutions of friction coefficient during sliding for potassium dichromate, ultra-sonicated potassium dichromate, sodium dichromate and ultra-sonicated sodium dichromat epoxy system at all concentrations for R1 applied regime are shown in Fig.3, Fig. 4, Fig.5 and Fig.6. A typical behaviour of the friction coefficient with the sliding distance for a sliding test can be observed for all the studied cases. After a very short period (approximately 8 m sliding distance) corresponding to the running-in the friction coefficient enters in steady-state conditions and remains approximately constant during the whole test [18], [19].

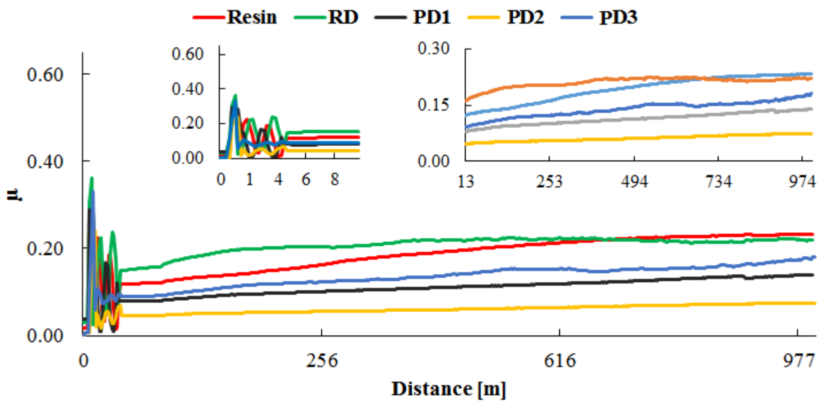


Fig. 3. *Potassium dichromate at all concentrations for R1.*

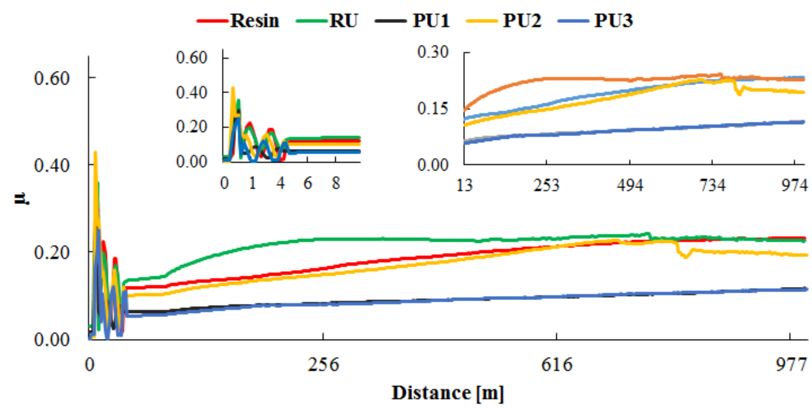


Fig. 4. *Ultra-sonicated potassium dichromate at all concentrations for R1.*

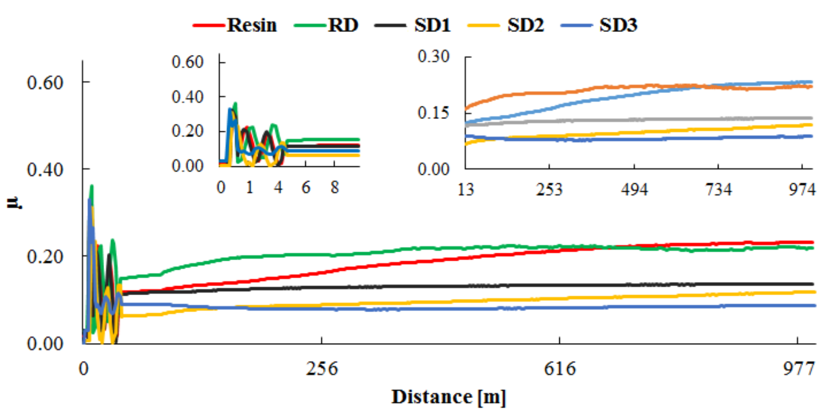


Fig. 5. *Sodium dichromate at all concentrations for R1.*

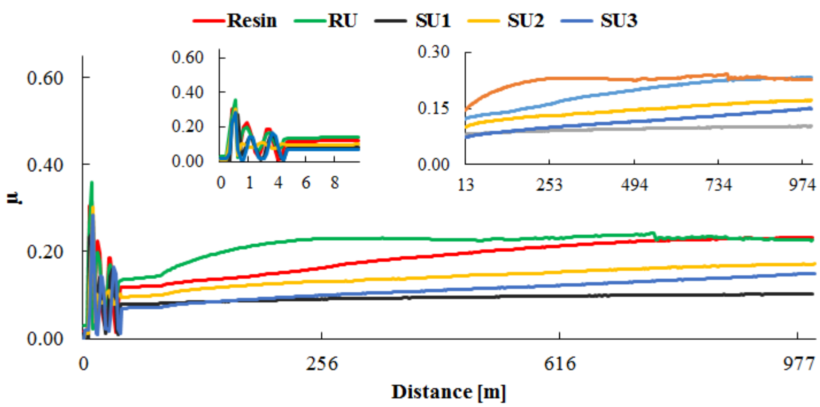


Fig. 6. *Ultra-sonicated sodium dichromat at all concentrations for R1.*

Based on these analyses, it becomes clear the positive effects of sodium dichromate regarding the evolution of friction coefficient, independent of the used concentration. We also noticed that ultra-sonication has no influence on friction coefficient evolution, the values for μ being almost the same for ultra-sonicated and no sonicated materials.

The evolutions of friction coefficient during sliding for potassium dichromate, ultra-sonicated potassium dichromate, sodium dichromate and ultra-sonicated sodium dichromat epoxy system at all concentrations for R2 applied regime are shown in Fig.7, Fig. 8, Fig.9 and Fig.10.

As it easily can be seen from the graphs regarding the R2 applied regime, the best friction coefficient evolution is for potassium dichromate and ultra-sonicated potassium dichromate for 1 alkaline ion of potassium dichromate at 5000 bisfenol A molecules.

Regarding sodium dichromat and ultra-sonicated sodium dichromat friction coefficient it has no major variations compared with neat epoxy.

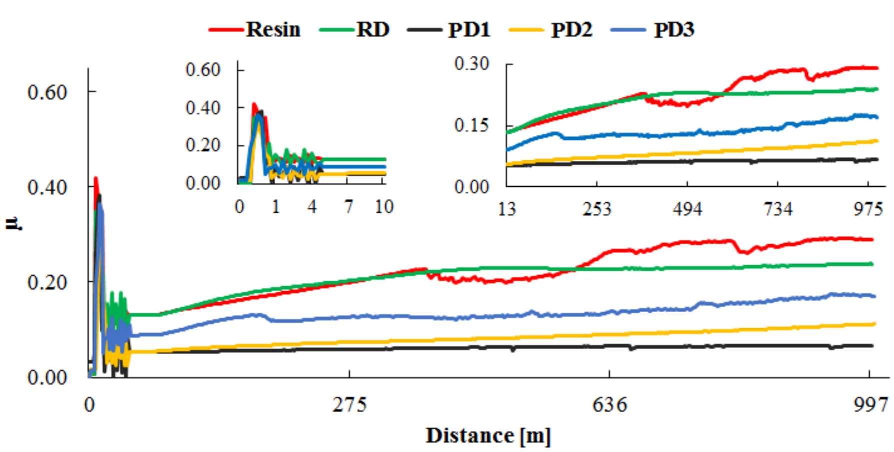


Fig. 7. *Potassium dichromate at all concentrations for R2.*

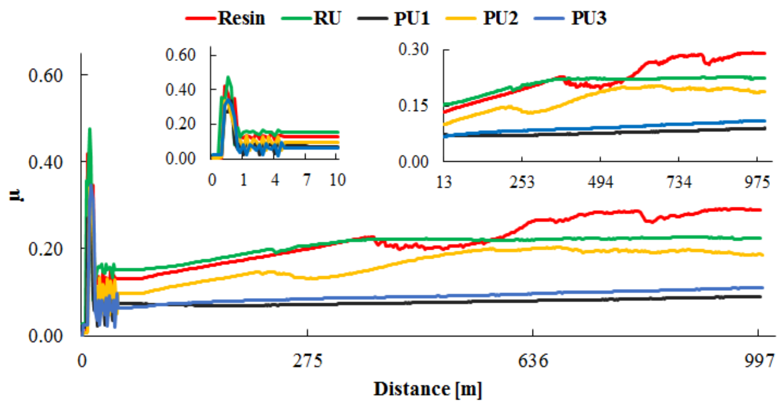


Fig. 8. *Ultra-sonicated potassium dichromate at all concentrations for R2.*

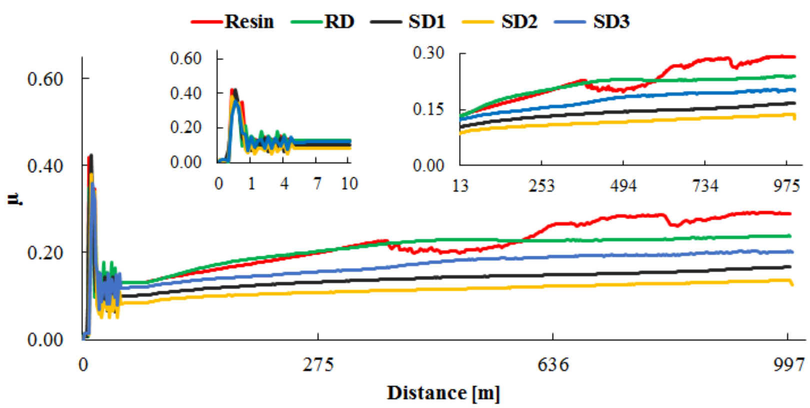


Fig. 9. *Sodium dichromate at all concentrations for R2.*

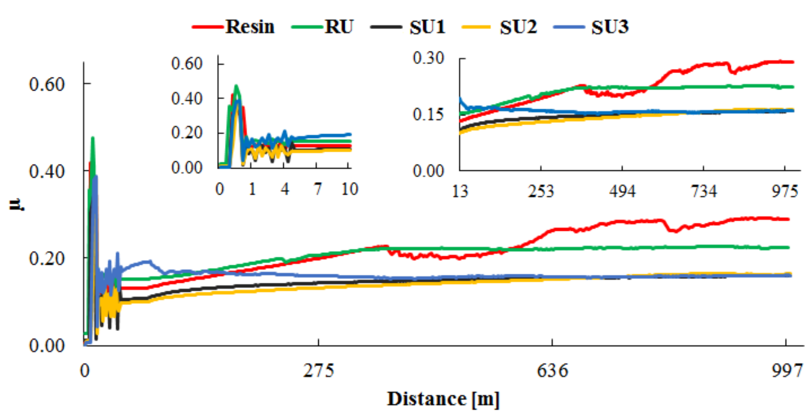


Fig. 10. *Ultra-sonicated sodium dichromat at all concentrations for R2.*

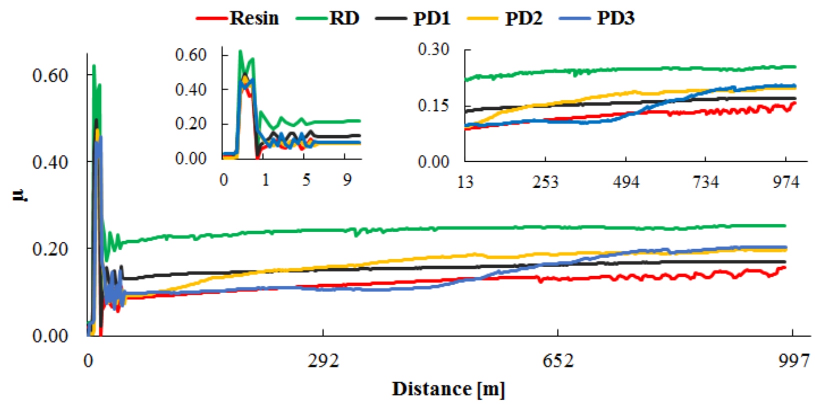


Fig. 11. *Potassium dichromate at all concentrations for R3.*

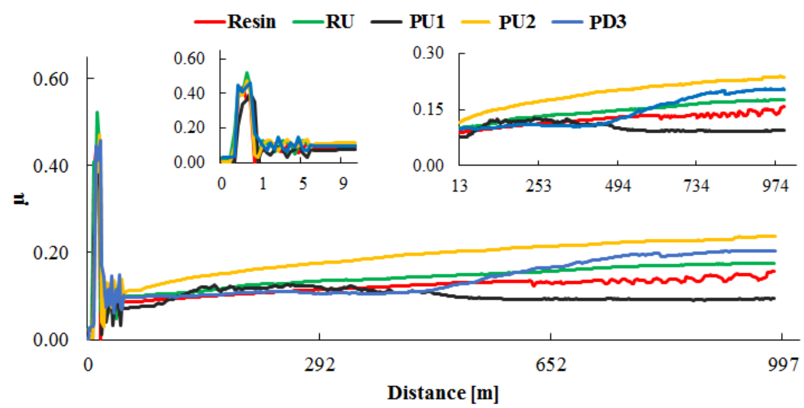


Fig. 12. *Ultra-sonicated potassium dichromate at all concentrations for R3.*

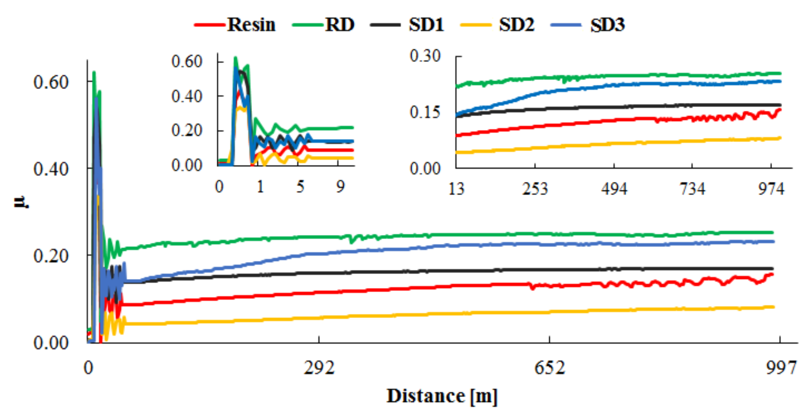


Fig.13. *Sodium dichromate at all concentrations for R3.*

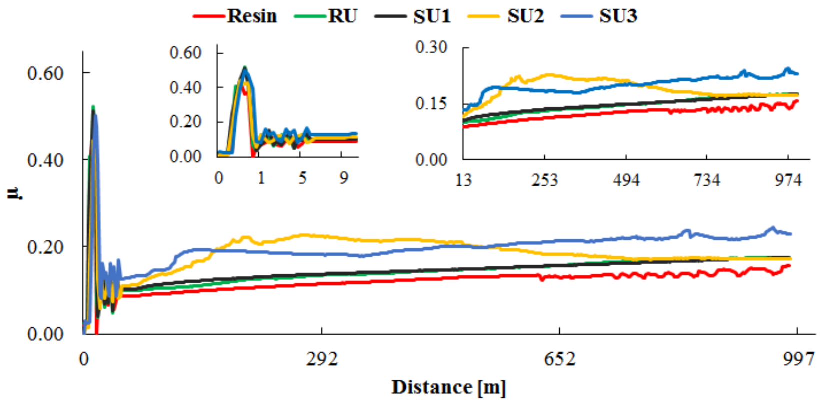


Fig. 14. *Ultra-sonicated sodium dichromat at all concentrations for R3.*

Figure 11, 12, 13 and 14 presents the variation of friction coefficient for R3 applied regime for both salts at all concentrations. In Fig. 11 and Fig. 13, for all composite tested it is shown that the values of friction coefficient are very much influenced by the nitro solvent. It can be seen from Fig. 12 and Fig. 14 that the friction coefficient is also influenced by ultra-sonication.

## 4. Conclusions

In this work, a complete characterization regarding the variation of friction coefficient of potassium and sodium dichromate doped epoxy is presented. Tribological tests have been designed in such way that the product of the loading force module and speed sliding module to be constant. Presence of salts used for doping improves the tribological behavior of materials. Friction coefficient shows generally the minimum values for tests with loads of 30N. Diluted resin has generally the weakest tribological behavior. Due to the very small weight loss, no wear could be analyzed.


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