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Friction characteristics of protein-glucose-thermoset composites

I Graur[1,2], V Bria[1], M S Drăghici[1] and C Munteniță[1]

[1]"Dunărea de Jos" University of Galati, Research and Development Centre for Thermoset Matrix Composites, Galați, Romania
[2]Diagnose and Measurement Group, Galati, Romania

E-mail: iulia.graur@ugal.ro

Abstract. Polymers are materials with a great spread and represent the center of the life comfort development. They have become since their discovery, indispensable to a modern prosperous society. In order to obtain optimal performance of the composite material, a broad variety of organic modification agents were used. The purpose of this study represents the development of modern composite materials modified with glucose particles and protein substances (gelatin and wheat gluten). The glucose-modified composite materials are used in the medical field.Gelatin is a protein derived from collagen, being bio-compatible and non-toxic. Wheat gluten is a vegetable protein used as a modifying agent to form composite materials that can be transformed into a bioplastic material. The following types of epoxy resins were used for this study: Epyphen RE 4020, Epoxy RESIN C, Epoxy RESIN HT. These composite materials are designed to withstand some mechanical, physicochemical, thermal properties and most valuable, tribological properties. Tribological tests aim to determine the friction coefficient. These tests are necessary to understand the tribological properties of composite materials and the field in which they can be used.

1. Introduction

The complex structure and unique properties of the composite materials typically depend on the nature of the materials constituting the matrix [1] and on the specific characteristics and complex geometry of the dispersion or reinforcement phase [2]. That is why it is necessary to handle separately the potential problems related to the structure and properties of the composite materials with particles, as well as the matrices that come into the composition of the composite materials [3]. Composite materials, one of the most rapidly growing classes of materials, are being used increasingly for tribological applications [4]. To obtain optimal performance of the composite material, a broad variety of organic and inorganic modification agents are used [5]. Because the polymer matrix must withstand high mechanical and tribological loads, it is usually reinforced with fillers. Almost all properties can be changed by incorporation of reinforcement or filler particles into a matrix but composite polymers have also the ability to control their frictional and wear behaviours sliding contacts [6]. The modifying agents are small particles dispersed in the matrix material [7], which can be easily made and embedded in the material [8]. The use of agents helps to improve the material by increasing the abrasion resistance and lowering the coefficient of thermal expansion [9]. Proteins are thermoplastic polymers of polar and non-polar amino acids that are capable of developing numerous intermolecular bonds and bearing various linkages [10]. Gluten is a vegetable protein [11], used as a modifier for the formation of composite materials, which can be transformed into a bioplastic material by casting. It is used because of its availability, good biodegradability and viscoelastic properties. These small molecules interact with the polymer chains, therefore reducing the forces, holding the chains together. Gluten-based composite materials are used to make food packaging as it improves food storage, having the ability to act as a barrier against water, oxygen, and light, therefore reducing oxidation of food. Gelatin is a protein derived from collagen, being bio-compatible and non-toxic. It is used most often for many biomedical applications. Gelatin films were used to protect food from light. The glucose-modified composite materials are used in the medical field. In medicine, it is mainly used as aqueous solutions for infusion [12]. Depending on their concentrations, they have numerous actions and directions. In industry, glucose is most often used in the nano-powders form. In this research paper, we studied the influence of test speed and applied pressure values on the friction coefficient of different epoxy matrix composites modified with different mixture of glucose, gelatin and gluten under dry sliding conditions against hard steel on a pin-on-disc apparatus. The friction coefficient behaviour of proteins such as glucose, gelatin and gluten, dispersed in polymeric matrix are topical [13-17].

2. Materials and method

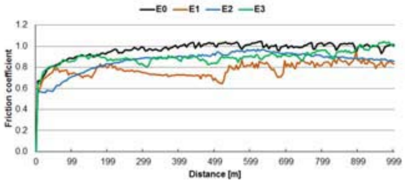
The preparationof the modified composite materials consisted of the addition of an amount of the glucose, gluten and gelatin powder modifying agent in an epoxy matrix [19-20]. The purpose of combining these materials is to obtain multifunctional properties, superior to the reference materials. Three epoxy resins were used in this study: Epiphen RE4020-DE 4020 (Bostik), Epoxy Resin C (R&G Gmbh Waldenbuch), Epoxy Resin HT-2 (R&G Gmbh Waldenbuch). For comparison of future results, we formed materials with the three unmodified resins with the abbreviated names as: E0, C0, H0. The amounts of organic agents used for the composite materials and samples coding are shown in Table 1. The resins were modified by adding different mixture percentage of glucose, gelatin and gluten. The molds consisted of polypropylene tubes with a diameter of 8 mm and a length of 200 mm. The test regimes for friction coefficient have been established as follows: a load of 15N and speed of 1m/s- R1; a load of 20N and speed of 0.75m/s-R2; a load of 25N and speed of 0.6m/s-R3. R1, R2 and R3 represents the friction coeficient regimes used for composite materials tests. Tribological tests were done 23°C for 1000 m distance. The tests were performed at three different regimes with three loads and three sliding speeds in order to respect the same product load-speed.

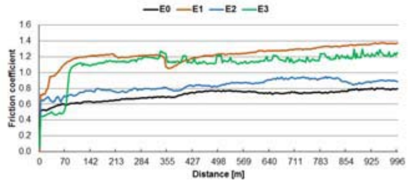
Table 1. Amounts of organic agents used for the composite materials and samples coding

Samples coding / Modifying agents, %	E1,C1,H1	E2,C2,H2	E3,C3,H3
Glucose	4	3	3
Gluten	3	4	3
Gelatin	3	3	4

3. Results

It can be seen for all the tested materials, a sudden increase in the first 10 meters of sliding after which the friction stabilizes.





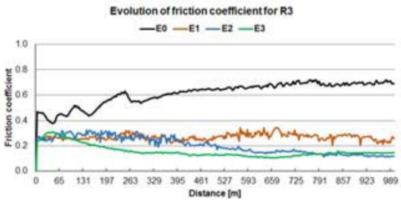


Figure 1. Evolution of friction coefficient for E epoxy system at all regimes

Figure 1 shows the evolution of friction coefficient for composite materials formed with E epoxy resin for all three test regimes. For all materials and for all three test regimes, a sudden increase of friction coefficient can be observed, after which it stabilizes. For the neat polymer (in this case E0) it can be seen that the value of friction coefficient does not change during the R2 test regime. For R1 and R3 regimes it can be seen a sudden decrease, followed by a sudden increase. The other materials exhibiting an increasing trend (in the case of the R2 test regime) and a decreasing trend (in the case of the R1 and R3 test regimes) of the friction coefficient during the sliding distance. For R1, the friction coefficient also has lower values than the neat resin E0.

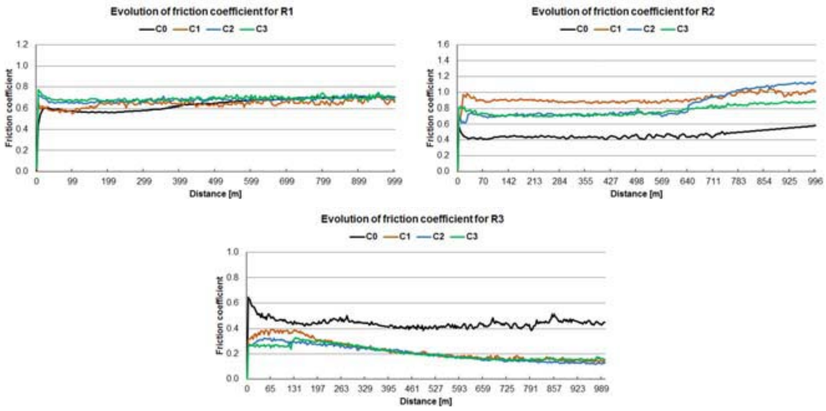


Figure 2. Evolution of friction coefficient for C epoxy system at all regimes

Figure 2 shows the evolution of friction coefficient for composite materials formed with C epoxy resin for all three test regimes. All materials behaviour for R1 regime is almost the same as the reference material C0. The friction coefficient is obviously increased for R2. Very low values of friction coefficient were obtained for R3.

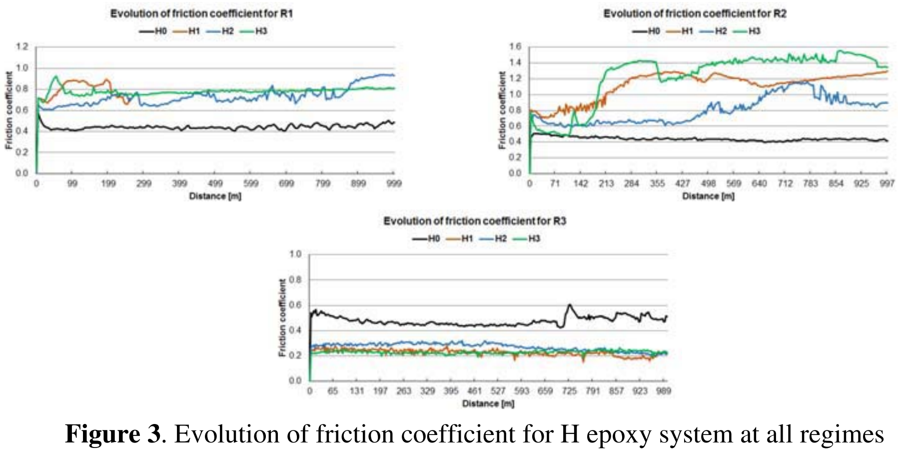


Figure 3. Evolution of friction coefficient for H epoxy system at all regimes

In Figure 3 it can be seen that for friction coefficient for composite materials formed with C epoxy resin, random friction coefficients develop throughout the test. For the test regimes R1 and R2, we note that the materials have almost the same friction behavior regardless of the applied regime. However, in R3 mode, all materials obtained from the epoxy resin H possess the lowest values compared to the neat material H0. The friction behaviour of composite materials were investigated using a TRM 1000 tribometer from Wazau on pin-on-disk geometry, with the pin made of analyzed material against steel disk (Fig.4).

Figure 4. Tribometer TRM 1000 from Wazau

4. Conclusions

The tribological analysis carried out on the three epoxy resins modified with proteins (gelatin and gluten) and glucose showed the following: E epoxy system: the friction coefficient is dramatically increased for R2, compared with the neat epoxy, by the addition of any percentage of proteins mixture and very low values were obtained for R3. For R1, the friction coefficient also has lower values than the neat resin E0.C epoxy system**:** for R1, C matrix composites modified with different mixture of glucose, gelatin and gluten, showed a friction stability compared to neat epoxy resin C0. The friction coefficient is obviously increased for R2. Very low values of friction coefficient were obtained for R3. H epoxy system: on R3, the smallest values of the friction coefficient are recorded.For R1 and R2, the friction coefficient is dramatically increased.Epoxy matrix composites modified with different mixture of glucose, gelatin and gluten showed a decrease in the friction coefficient varion for a load of 25N and speed of 0.6m/s-R3.

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