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An experimental investigation of the effect of the type of nanostructured reinforcements on the mechanical and tribological properties of epoxy based nanocomposites

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ABSTRACT: In this paper, the effect of three different types of nanostructured reinforcements on the mechanical and tribological properties of nanocomposites are investigated. Carbon nanotube, nanoclay and nanographene oxide with equal weight percentages and under similar environmental conditions are added into the epoxy resin. To achieve uniformly dispersed nanoparticles within the epoxy matrix, mechanical stirring with ultra-sonication is utilized. After degassing process, tensile and wear test specimens were made according to the relative standards. Three samples of each nanocomposite were prepared and tested. Young's modulus, ultimate tensile strength, strain at break point and toughness of the specimens were extracted from the stress-strain curve using the tensile test. Dry wear test was performed at 20N, 60N and 100N loads using a disk on pin testing machine at room temperature. The results showed that in the sample containing carbon nanotubes, the ultimate stress increased by 16% and the strain at the break point increased by 27% compared to pure epoxy. Also, carbon nanotube/epoxy and nanoclay/epoxy nanocomposites showed the highest wear resistance compared to other samples, so that in the sample containing nanoclay reinforcement, a 60% decrease in the amount of wear rate was observed compared to the pure epoxy sample.

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1- Introduction

Many industrial demands cannot be met using conventional materials. High strength and light materials with acceptable impact and abrasion resistance are required in these industries [1]. Composite materials, if well designed, usually exhibit improved properties. In some applications, epoxy resins are used as the matrix in the construction of fibrous composites. Baked epoxy resins have good electrical-mechanical properties, dimensional stability and chemical and heat resistance. Due to the diversity of these resins in environmental and thermal cooking conditions, they are used in various industries. [1, 2]. Furthermore, during the last two decades, using nanomaterials, as a reinforcement phase, in the structure of composites is investigated by many studies. Numerous studies have shown that adding a small amount of nanofillers significantly improves the mechanical properties of the resin [3-5]. Abrasion occurs between two or more parts due to the contact and friction and causes surface damages. To prevent wear, friction should be reduced by various methods such as surface lubrication and using abrasive resistant materials. Extensive research has been conducted on the use of nanomaterials to improve the tribological performance of composites [6-9].

To the best knowledge of the authors, little research has been focused on the tribological properties of nanocomposites with various nanofillers. In this research, using an experimental method, the effects of adding three different nanostructures into the epoxy resin, on the mechanical and abrasive properties of the obtained nanocomposites have been investigated. Carbon NanoTube (CNT), graphene oxide nanoplate (NGO), and NanoClay (NC), with equal weight percentages, have been added into the epoxy matrix. The Environmental conditions, the method of homogenization of nanostructures into the resin and the molding and curing processes have been the same to make all three types of nanocomposites. Tensile and wear test specimens were made according to ASTM standards. To determine the mechanical properties and abrasion resistance of the fabricated specimens, the simple tensile tests and pin on disk experiments were examined, respectively.

2- Methodology

In this study, in order to distribute nanostructured fillers in the resin, an ultrasonic bath and a magnetic stirrer were used according to Fig. 1. The mixture of epoxy resin and nanostructure reinforcement was first placed into the ultrasonic bath at 40 °C for one hour. Then the resulting mixture was placed on the magnetic stirrer for one hour and finally, to achieve a homogeneous dispersion, the ultrasonic bath was used for an hour.

The degassing process was performed in the desiccator under vacuum pressure for 30 minutes, then the mixture

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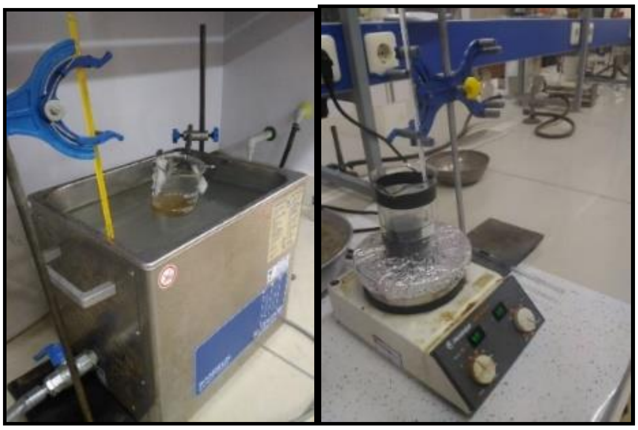

Fig. 1. Ultrasonic bath (right) and magnetic stirrer (left)

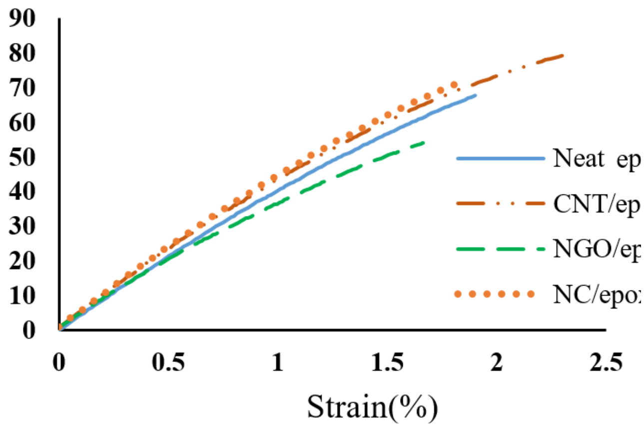

Fig.2 Stress-strain diagrams of pure epoxy and nanocomposite specimens

was transferred into the prefabricated silicon molds and the samples were cured for 30 hours at 30°C. To perform the tensile tests, An Instron hydraulic universal testing machine is employed. Moreover, the wear tests were examined using an Iranian pin on disk device.

3- Discussion and Results

Stress-strain diagrams of pure epoxy, CNT/epoxy NGO/epoxy, and NC/epoxy are illustrated in Fig. 2.

According to the experimental results, it seems that suitable surface adhesion between carbon nanotubes and epoxy matrix, increases the stress transfer between carbon nanotubes and epoxy [10]. Reduction of ductility and tensile strength of nano-graphene composite due to accumulation of micro-fillers, micro-cavities have also been observed in Omesh studies [11].

To obtain the weight loss of the samples, after each wear test, the samples were cleaned with acetone and then the weight loss of the specimens was recorded. Weight loss results are summarized in Table 1.

At load 100N, the lowest weight loss is related to the NC/epoxy sample. The weight loss of this sample is about 60% less than that of the epoxy sample. Moreover, as the results show, the lowest coefficient of friction between the specimens and the abrasive pin is reported for NC/epoxy.

Table 1. Weight loss (gr) of pure epoxy and nanocomposite specimens at different vertical loads

Composite	20 N	60 N	100 N
Epoxy	0.0008	0.0026	0.0063
CNT/epoxy	0.0001	0.0005	0.0036
NGO/epoxy	0.0001	0.0007	0.0029
NC/epoxy	0.0001	0.0006	0.0025

4- Conclusions

In this study, the effects of adding three types of nanostructured reinforcements including carbon nanotubes, nanographene oxide, and nanoclay into the epoxy resin on the mechanical properties and abrasive resistance of the nanocomposite specimens, under similar conditions, were investigated. Studies show that reinforcing epoxy resin with 1.5% carbon nanotubes has the greatest impact on the mechanical properties of epoxy. In this sample, the elastic modulus increased by 6%, the ultimate stress increased by 16%, and the strain at the break point increased by 27% compared to those of the pure epoxy sample. The NC/epoxy specimen also shows good mechanical properties with a slight difference compared to that of the CNT/epoxy sample. Weak mechanical properties of the NGO/epoxy sample can be attributed to the difficulty of properly distributing the graphene oxide plates into the matrix material, by conventional methods. All in all, three types of nanostructured reinforcements increase the wear resistance of the samples. The NC/epoxy specimen, with the lowest weight loss during the pin on disk test, shows the best abrasion resistance among the studied specimens.

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