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FRICTION AND WEAR OF EPOXY REINFORCED BY IRON NANO PARTICLES

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ABSTRACT

Epoxy-Iron composite specimens were prepared by adding different weight fractions of iron nano particles (0, 10, 15, and 20 wt. %) to the epoxy matrix. Friction and wear testing as well as hardness testing were conducted on the specimens. The coefficients of friction of the produced materials were determined unreinforced epoxy showed the highest coefficient of friction, while epoxy composite with 15 wt. % Fe showed the lowest coefficients of friction. Hardness of the produced composite measured using the shore D hardness increased as more Fe particles were added to the epoxy. Topography of the specimens after wear testing was examined using Scanning Electron Microscope (SEM). The SEM observation showed good agreement with the wear testing results.

KEYWORDS

Epoxy, iron nano particles, epoxy composite, mechanical test, friction and wear.

INTRODUCTION

As a continuation of the researches on the improvement of tribological performance of polymeric nano composites, [1 - 4], the present paper discusses mechanical behavior, friction and wear of Epoxy filled iron nano particles. The composite means two or more from different materials participation sharing subscription association together fractions volume or weight percentages to produce new material of better properties, and in general the composites are classified into three kinds as follows; first fiber composite, where the reinforced material is fibers included matrix material. The second is laminated composite that contains two or more layers from different materials and are in engagements together, [5, 6].

Nano composites are compatible with conventional polymer Processing, thus avoiding the costly stay up required for the fabrication of conventional fiber-reinforced composites. When the fillers possess dimensions on the order of nanometers, even a small concentration can lead to enhancements in properties, unprecedented in conventional composites, [7]. The unique properties of polymer nano composites are attributed to the high filler surface area-to-volume ratio, which results in significant interfacial areas of contact between the polymer and the particles. The large interfacial

areas of contact enable a substantial fraction of polymer segments to interact directly with the filler particles, even at low particle concentrations. Mechanical and tribological properties of polymer nano composites are not as a simple as the addition of individual properties of the components, and depend on many factors and synergetic interactions. A new group of polymer nano composites based on integrating fullerene-like fillers into conventional polymer matrix has been developed in the last years, [8].

A number of polymers can be considered to be competitive materials for tribological applications because of their low friction coefficients against steel counterparts, good damping properties, and self-lubricating ability. In order to meet the special needs of tribological applications .polymer composites can be designed by selecting the correct composition and choosing the appropriate manufacturing process. The improvement of mechanical and/or tribological properties of polymer by incorporation of particulate filler materials has been widely studied, [9]. Under extreme friction conditions, however, conventional polymer composites are usually not effective for antiwear and friction reduction for example, under heavy load. The nanoparticle reinforced polymer composites are the most rapidly growing class of materials due to a good combination of high strength and modulus at very low levels of loading, [10].

Polymeric composite materials are of versatile scientific and technological significance due to their enhanced mechanical properties, and Epoxy resin as a part of polymeric materials is widely used as an electrical insulation material, [11]. Metal particles added to polymeric materials lead to composite with higher density, improved electrical and thermal conductivity, and are therefore of particle interest for specific applications, [12].

The aim of the present study is to test friction, wear and hardness of epoxy specimens filled by iron particles of different contents.

EXPERIMENTAL PROCEDURES

Composites preparation

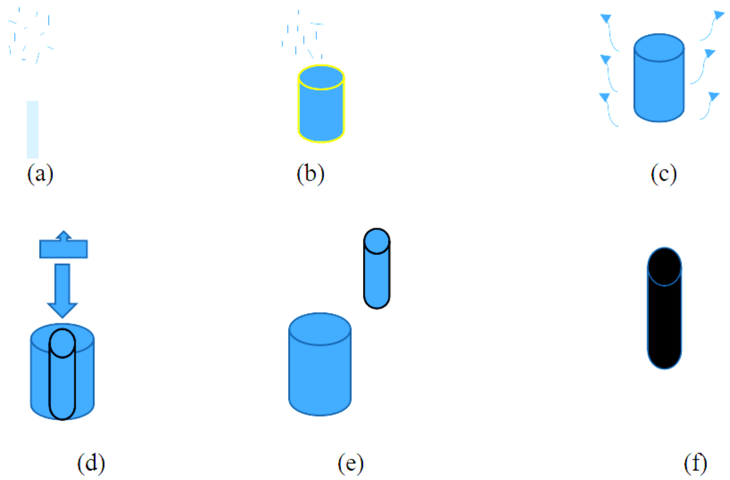

Fig. 1 Method of preparation of specimen; (a) Fe nanoparticles. (b) Mixing. (c) Pouring. (d) Compression. (e) Removing. (f) Final shape of specimen.

Epoxy 150 and hardener are mixed by 2:1 for test specimens, then they are mixed with nano particles of iron (FeNPs) content of 10 wt. %, 15 wt. %, and 20 wt. % for a quarter of an hour. The internal surface of the die is greased. The mixture is poured into the die. The specimen is molded in dimensions of 25 mm diameter and 130 mm long. The specimens are turned to have the final dimensions of 7 mm diameter and 10 mm long. Figure 1 shows the method of preparation of specimen used in this study.

Friction and wear testing

To evaluate the coefficient of friction of the specimens, cylindrical specimens (9 mm in diameter and 12 mm in length) of each condition were fabricated. Friction force was evaluated through subjecting the specimens to friction testing at different normal loads against emery paper (1000, 120, 220 grit size number) counterface. For each normal load, the coefficient of friction was determined using the relationship:

$$\mu = F_f / F_N \qquad (3\text{-}1)$$

Where μ is the coefficient of friction, F_f , F_N friction and normal load .The test conditions were; sliding speed = 180 rev/min, load = 2, 4, 6, 8 and 10 N, time = 10 second.

RESULTS AND DISCUSSION

Effect of Fe NPs on Friction coefficient

Friction coefficient μ versus normal load at 120, 220 and 1000 grit size emery paper are shown in Figs. 2 - 4, respectively for tested specimens. For all polymer materials, the coefficient of friction starts with a running-in period followed by a steady-state period. It is believed that, within the running-in period, ridges are formed on the surface of the polymer, but within the steady-state period, these ridges disappear and wear debris covers the surface, which leads to lower friction coefficient values. These conclusions were verified by the SEM observation, Figs. 5 and 6. This is typical friction behavior for polymeric materials, [13]. From Figs. 2 - 3, it is clear that friction coefficient μ decreased with increasing normal load at all content of FeNPs used. As it evident in Figs. 4 - 6, the specimen containing 15 wt. % of Fe NPs at 8 N presents the lowest friction coefficient followed by the specimen containing 20 wt. % of Fe NPs at 6 N, then the specimen containing 10 wt. % of Fe NPs at 4 N and lastly the pure specimen at 2 N. As can be seen in Fig. 2, the highest value of the coefficient of friction is 0.87 at normal load 2 N in the pure specimen, while the lowest one is 0.198 at normal load 8 N and concentration of FeNPs 15 wt. %. On comparing the concentration of Fe NPs, it is found that the pure specimen showed the highest friction coefficient, while the specimen containing 15 wt. % of FeNPs had the lowest friction of coefficient. The friction coefficient follows this order: the pure specimen > 10 wt. % of Fe NPs > 20 wt. % Fe NPs > 15 wt. % of FeNPs. In Fig. 3 the friction performance of specimen reinforcement with 15 wt. % FeNPs at low load gives the highest value at 220 grit size. The reason may be due to the change in phase behavior of polymer matrix such as formation of crystalline modification, [14].

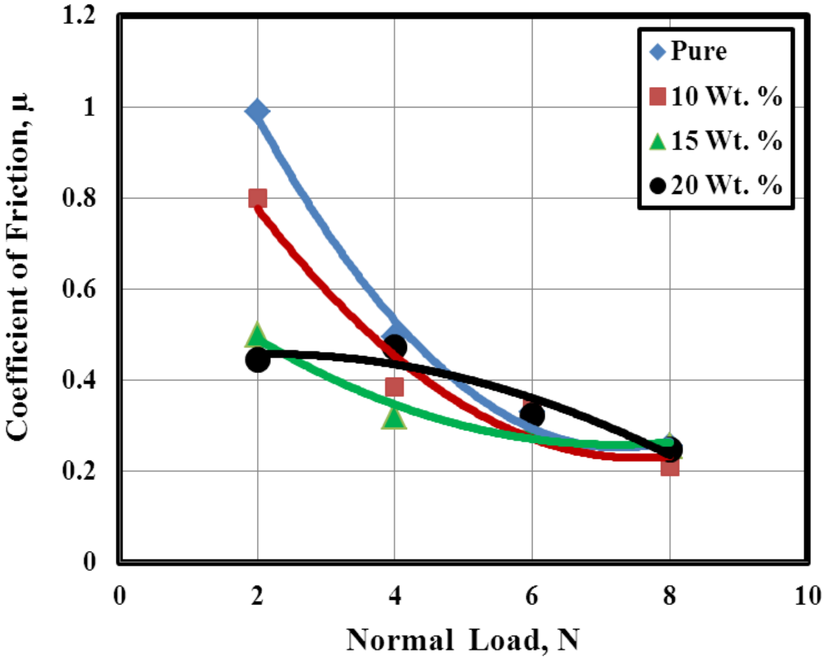

Fig. 2 Effect of normal load (N) on coefficient of friction for specimen at 120 grit size number at 10 second.

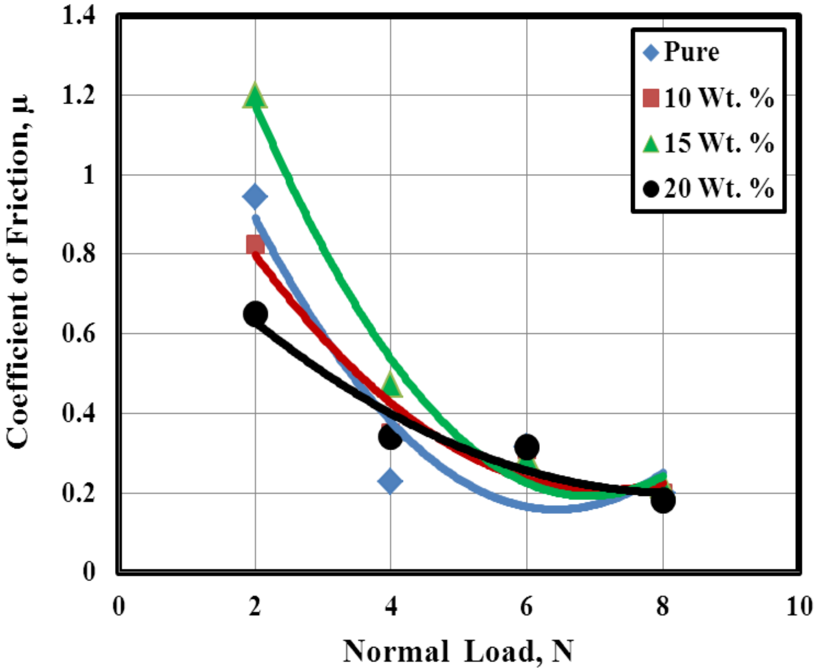

Fig. 3 Effect of normal load (N) on coefficient of friction for specimen at 220 grit size number at 10 second.

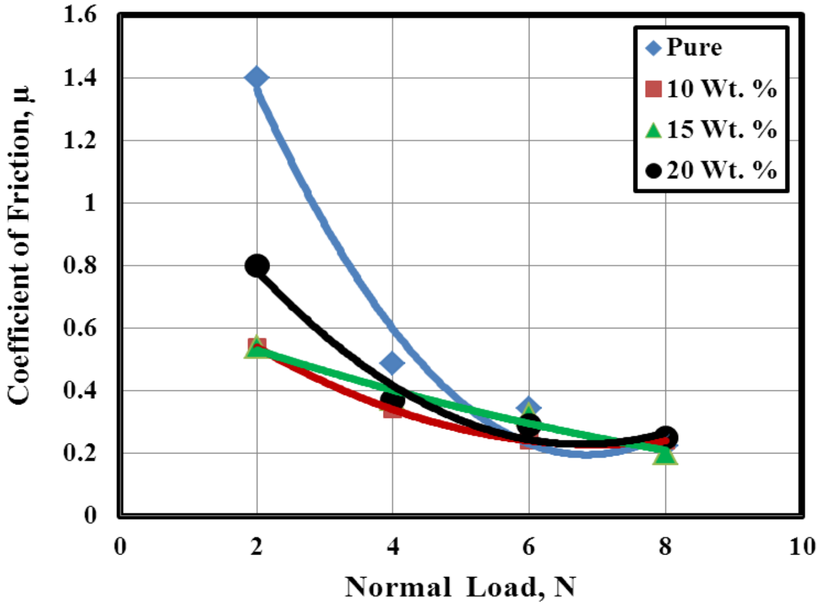

Fig. 4 Effect of normal load (N) on coefficient of friction for specimen at 1000 grit size number at 10 second.

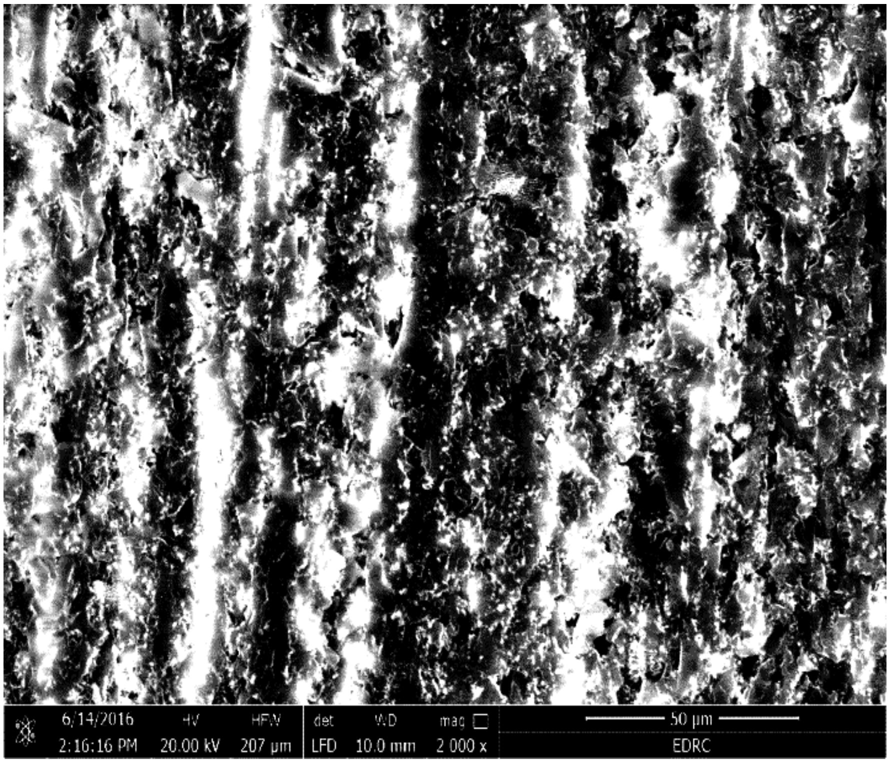

Fig. 5 Formation of ridges on the specimen surface,the sem of Pure epoxy Specimen at Friction's conditions (1000 Grit size Number, 10 Second, 2N) , Microscopic Examination(Magnification 2000x) .

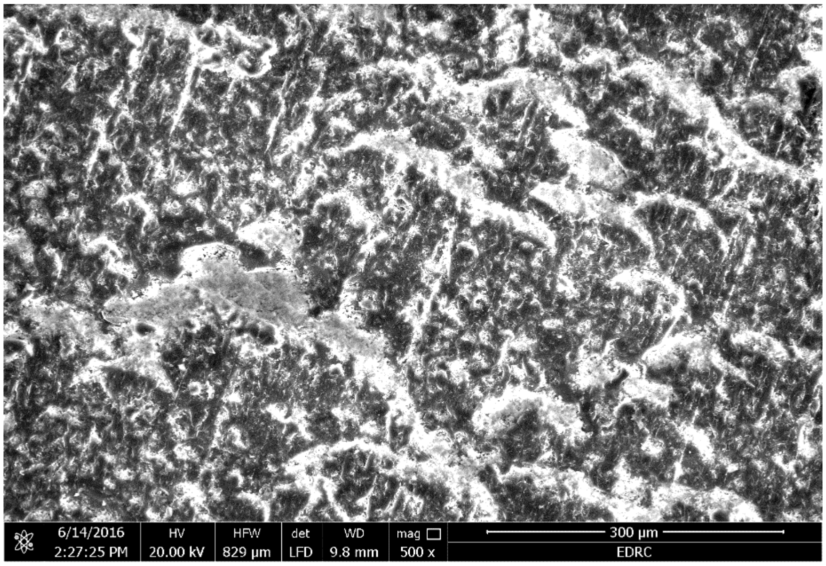

Fig. 6 Wear debris cover the surface during the steady state period, (Magnification × 2000) .

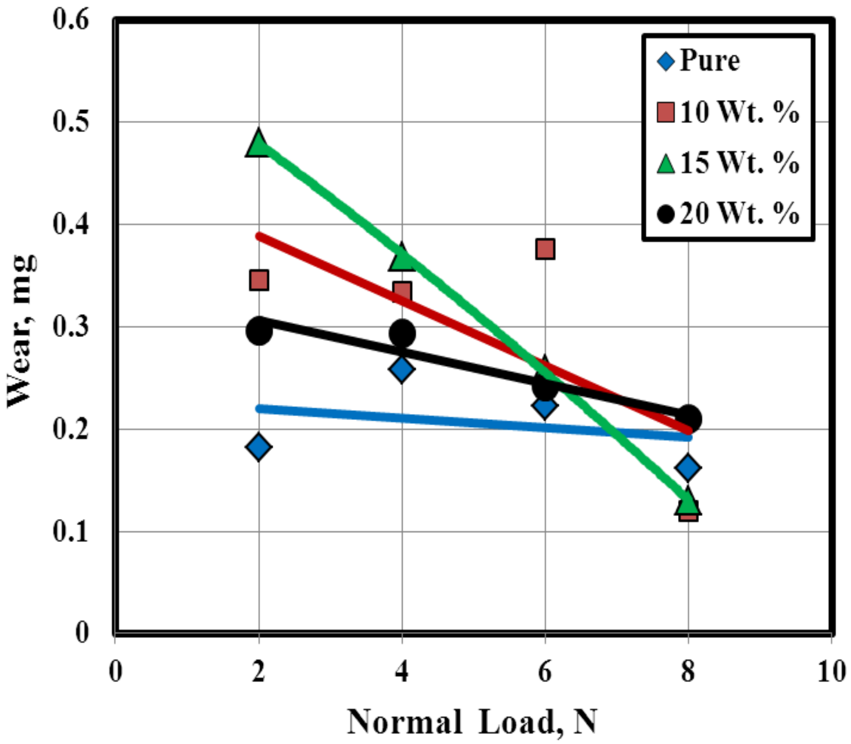

Fig. 7 Effect of normal load (N) on wear for specimen at 120 grit size number at 10 second.

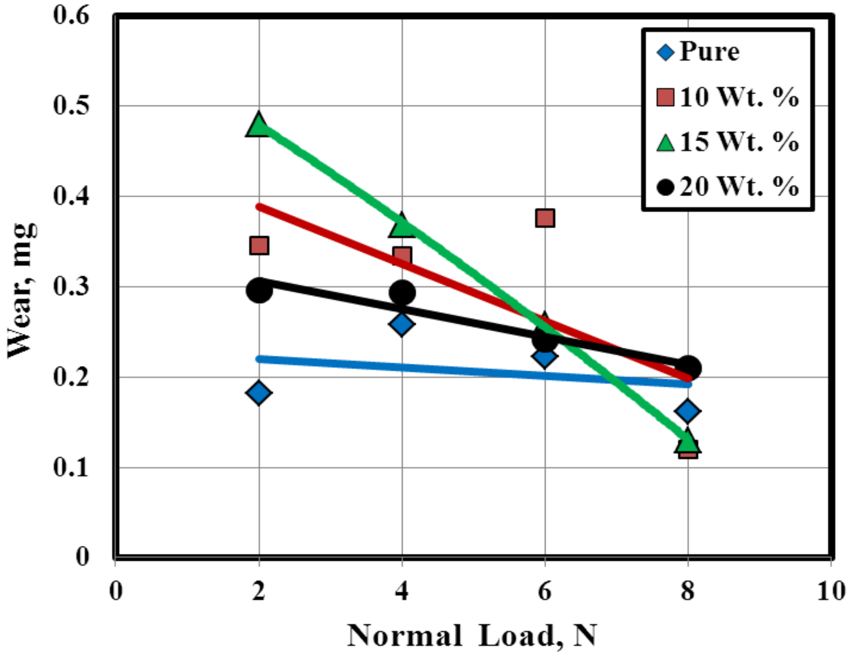

Fig. 8 Effect of normal load (N) on coefficient of wear for specimen at 220 grit size number at 10 second.

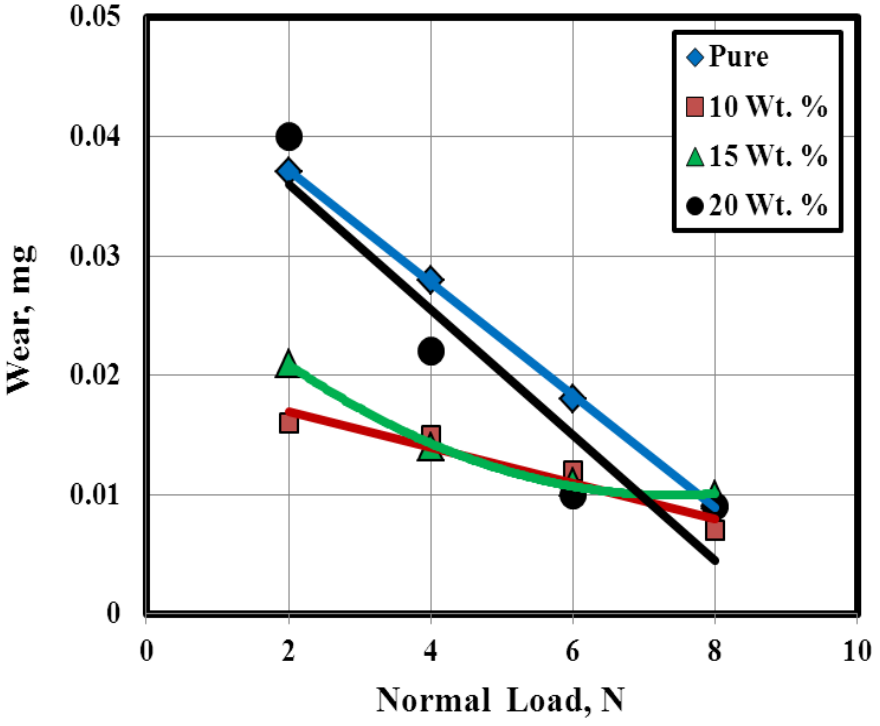

Fig. 9 Effect of normal load on wear for specimen sliding against 1000 grit size number at 10 second.

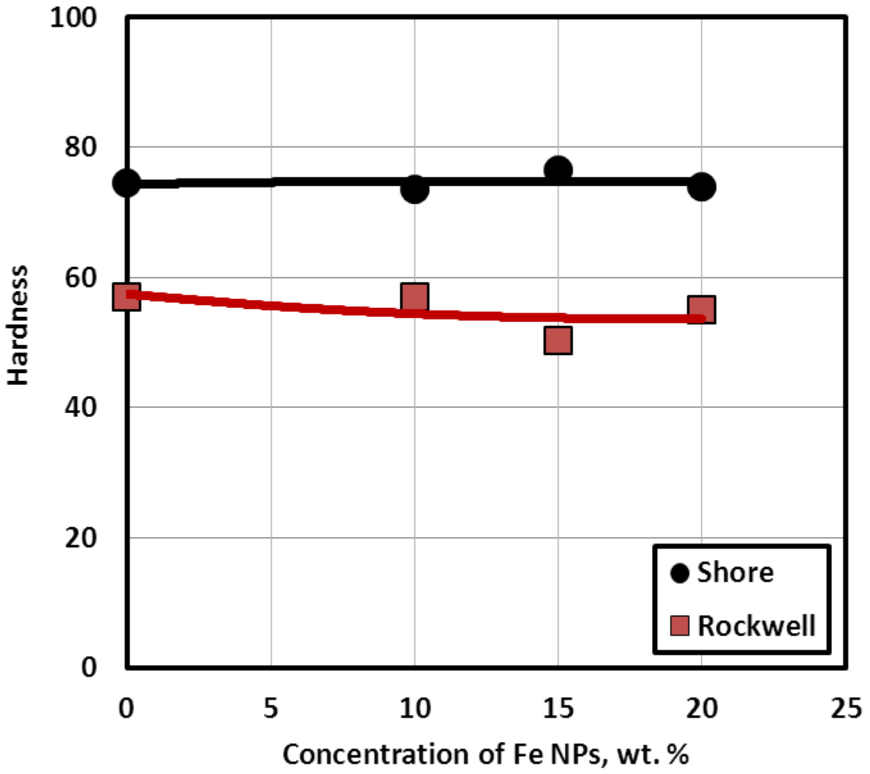

Fig. 10 Shore D Hardness values as a function of iron content.

Effect of FeNPs on Wear

Wear versus normal load of 120, 220 and 1000 grit size are shown in Figs. 7 - 9, respectively. The tested specimens showed that wear decreased with increasing the normal load. As evident in Figs. 7 - 9 the specimen containing 15 wt. % exhibits the highest wear at 8 N at 120 and 220 grit size number. The pure specimen exhibited the lowest wear at 8 N at 120 and 220 grit size. The wear appears to depend on the content of FeNPs; as the content of FeNPs increased, the wear first decreased, and then increased. It is shown that the addition of FeNPs into was not pronounced when sliding against 120 and 200 grit size emery papers. The effect was clear at 1000 grit size that the filled test composites displayed significant enhancement in wear resistance. Besides, the decrease of wear with increasing applied load may be attributed to the fact that as the load increases the polymeric matrix suffers from plastic deformation that decreases its shear strength and consequently removed material decreases while plastically deformed material increases.

Effect of FeNPs content on hardness

Fig. 10 represents the shore D hardness values as a function of iron content in the tested composite specimens. It is clear that shore hardness of the tested material decreases with increasing the concentration of FeNPs from 0 to 10 wt. %, then increases with increasing the concentration of FeNPs from 10 to 15 wt. % and it decreases with increasing the

concentration of FeNPs from 15 to 20 wt. %. The shore hardness values of epoxy/iron particles composite increased when the iron particles percentages increased, [15].

CONCLUSIONS

The main remarks of conclusion can be summarized as follows:

1. The shore hardness values of epoxy/ iron nano particles composite increased when the iron particles contents increased from 10 wt. % to 15 wt. % and decreased when the iron particle concentration increased up to 20 wt. %.

2. The pure specimen showed the highest friction coefficient, while the specimen containing 15 wt. % of FeNPs had the lowest friction of coefficient.

3. The highest wear was produced by 15 wt. % content of FeNPs, while the lowest wear was produced by the specimen without FeNPs at 120 grit size at 8 N.

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