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TRIBOLOGICAL BEHAVIOR OF EPOXY COMPOSITES FILLED BY CARBON NANO-PARTICLES

Samy A. M.

Production Engineering and Mechanical Design Dept., Faculty of engineering,
Minia University, P.N. 6111, El- Minia, EGYPT.
E-mail. Abdelhalim96@hotmail.com

ABSTRACT
In recent years we needed to new bearing materials, such as nanotechnologies, new developments are under progress and will certainly engage to engine friction reduction. However, for a minimum friction bearing is solution, it is significant to design or to establish new solutions with estimate to running engine terms and reliability objective. In this work investigate the wear resistance friction coefficient and friction coefficient of epoxy composites reinforced by carbon nano-particles filled by different oil concentration. Sliding of composite material against steel surface was investigated in order to improve materials with high wear resistance and low friction coefficient which can be used as bearing materials.

Experiments were carried out at non lubricant sliding condition. The test specimens in the form of cylindrical shape with 7 mm diameter and 30 mm length of epoxy resin filled by carbon nano-particles were tested. Pin on disc tribometer was used to implement the friction and wear tests.

Based on the experimental observations, it was found that the addition of carbon nano-particles to epoxy enhanced the wear resistance and reduces the friction coefficient. The minimum value of friction coefficient (0.18) was observed at 7 % carbon nano-particles and 0.4 % oil content. Wear resistance can be increase for epoxy composite by increasing carbon nano-particles up to 10% and 0.3% oil. Increase of oil content decreased the bonding of epoxy and steel surface and reduce friction coefficient and wear losses.

KEYWORDS
Wear resistance, friction coefficient, epoxy and carbon nano-particles

INTRODUCTION
In the recent years, There is an increasing needed to introduce new bearing materials produced by nanotechnologies. However, for a minimum friction bearing, it is significant to design or to establish new solutions with estimate to running engine terms and reliability objective. The later design trend is to upgrade engine efficiency thanks to

engine down-speeding and to engine down-sizing. These progresses mean that engine bearings are operating in more critical conditions than ten years ago. From a practical observation, oil temperatures are higher as contact pressure and cycles are more critical, [1]. It is clear that minimum friction for bearing design has to go side by side with progress in reliability. Such as, an easy friction reducing could be obtained by decreasing oil viscosity. However, some lubricated composition could begin to operate in a blended lubrication regime with a possibility wear problem. The compositions usually interested by this lubrication regime are camshaft bearings, piston rings and tappets.

Nanocomposite as a modern composite material has attracted many attention from research institutes and industry in the last ten years due to the potential growing to the mechanical/tribological properties of new composites, [2-4]. It has been exceedingly reported that the addition of micro-sized or nano-sized fillers into polymer matrix can significantly upgrade the mechanical property and tribological property, [5-6]. Properties of the nano-composite generally depend on many factors such as the size and type of the fillers, the proportion loading and the dispersal of the particles [6- 8]. Epoxy resin is most used in electronic devices and isolating system in the power system applications. The use of micro-sized particles as fillers when manufacturing epoxy resin is already a popular practice in industry. By adding nano-sized particles into micro filler reinforced epoxy resin, the properties of material could be moreover improved. Inorganic particulate filled epoxy composites have been widely studied during the previous two decades due to their increasing applications in coatings, electronic packaging and dental restoratives, [9 - 10]. The particles in these composites are mostly of micrometer size. Use of nano-particles as filling in epoxy composites is nowadays attracting a major deal of concern from materials scholar, technologists and industrialists, [11 – 12]. These new nano-composite systems could have widely application possibility with their adorable optical, electrical and magnetic properties. The success of their technical purposes depends to a large range on a good realization of both the nature of the nano-composites and the linkage between structures, properties and processing. Clearly, their mechanical reaction is essential to the comprehension. In specially, an understanding of the wear properties of the composites is significant in some applications.

In order to improve the tribological and mechanical properties, electrical conductivity, thermal conductivity, magnetic properties of epoxy, diversity of nano-fillers and additives including Fe oxide and Fe nano-particles, carbon nano-fibers, nanoclay, graphene, Zinc oxide and alumina have been used to fillers epoxy nano-composites. Through the various nano-fillers for make the high performance of epoxy nano-composites, carbon nano-materials are more attractive because of their wonderful physical properties, [13 - 15]. The performance of carbon and epoxy is significantly improved if regular dispersion of carbon nanofillers in the matrix, and strong interfacial bonding between the filler and the matrix are accomplished. Weak interfacial bonding restricts load transfer from the epoxy matrix to the fillers. So, strong interface bonding and identical dispersion of fillers are very important for maximizing reinforcement. However, carbon nano-materials generally tend to re-aggregate and mound because of the strong force and/or high surface area, limited their applications in polymer nano-composites. To control these challenges, ultra-sonication, high shears mixing, surfactants, chemical treatments using weak acids, and fictionalization has been applied

[16]. Successful strategies to improve the dispersion and interface interaction of carbon nano-materials in a polymeric composite have been homogeneous reviewed by many researchers, [17- 22].

The oxidation layer produced due to tribo-oxidation of steel counterparts across to high friction coefficient between the sliding pairs. When chrome-plating is used as counterpart, graphite materials transfer command the transfer film formation, [23]. Where that, nano-composite, displayed the best performance when sliding against counterface of 100Cr6. The nano-particles have the ability to form a protective film against severe tribo-oxidation of the steel counterface. Furthermore, it shows that the transfer films of the hybrid nano-composites have different load carrying capacity when sliding against different counterface.

The present work investigates the coefficient of friction and wear resistance for epoxy composite filled by carbon nano-particles and base oil.

EXPERIMENTAL

Experiments were done by using pin on disc, Fig. 1. It consists of an electric motor connected to the gear box used to reduce the velocity and convert the direction of motion from horizontal motion to vertical one. The shaft of the gear box is connected to the friction disc that acts as a counterface. The specimen is held by chuck at the end of vertical column connected to horizontal load cell connected to digital screen which displays the friction force.

Test specimens were designed in the form of cylindrical shape with cross section of 7 mm diameter and 30 mm length. The test specimens were loaded by 1 kg dead weight against counterface of the carbon steel disc.

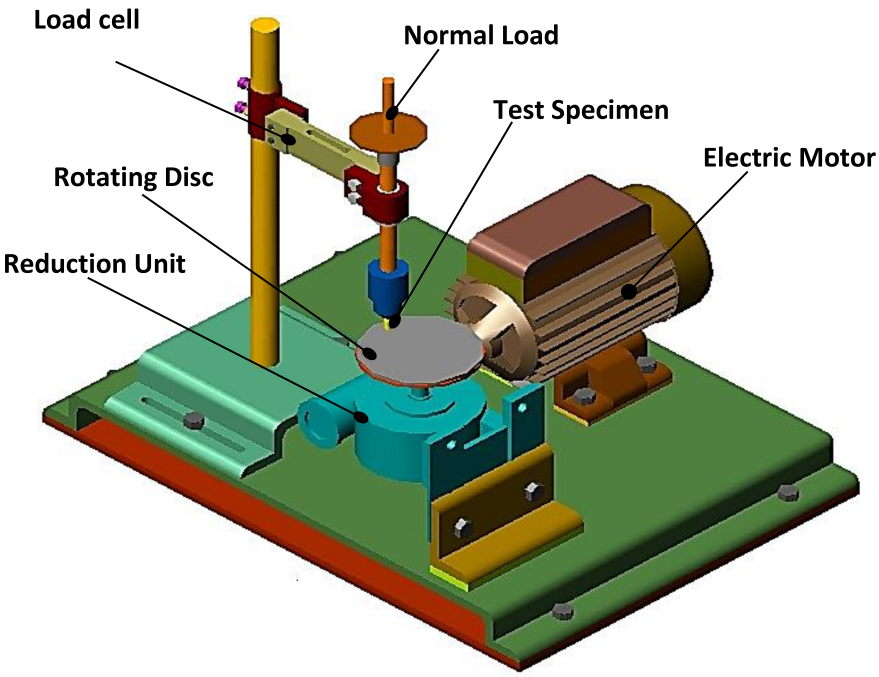

Fig. 1 Arrangement of friction test rig.

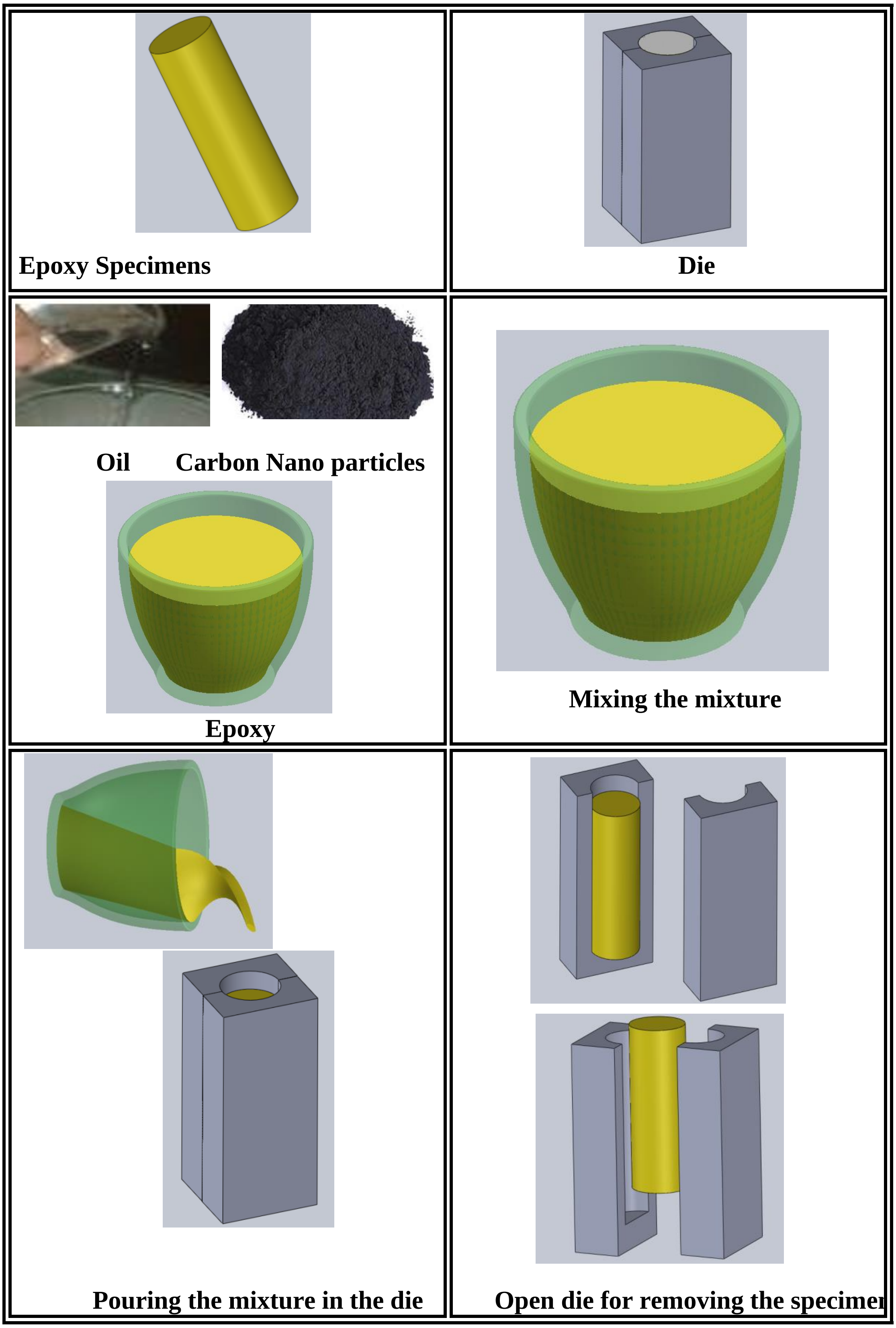

Fig. 2 Steps of test specimens preparations.

Test specimens were prepared by mixing the epoxy by carbon nano-particles of 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 wt. % content, and paraffinic oil by 0, 0.1, 0.2, 0.3, 0.4 and 0.5 wt.

% contents. Friction coefficient was determined through the friction force measured by the deflection of the load cell divided on the normal load, while wear was measured by the difference between the weight of specimen before and after test using a digital balance of 1.0 mg accuracy. The carbon nano-particles with (100 nm). Test specimens were prepared by various procedures was shown in Fig. 2.

RESULTS AND DISCUSSION

The electro-scan microscopic for pure epoxy test specimens was shown in Fig. 3.

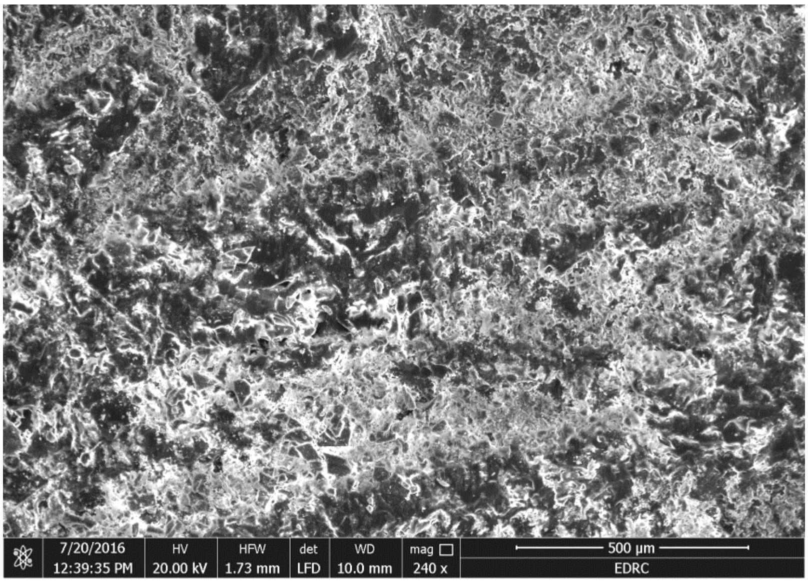

Fig. 3 Scanning electron microscopic for pure epoxy test specimens.

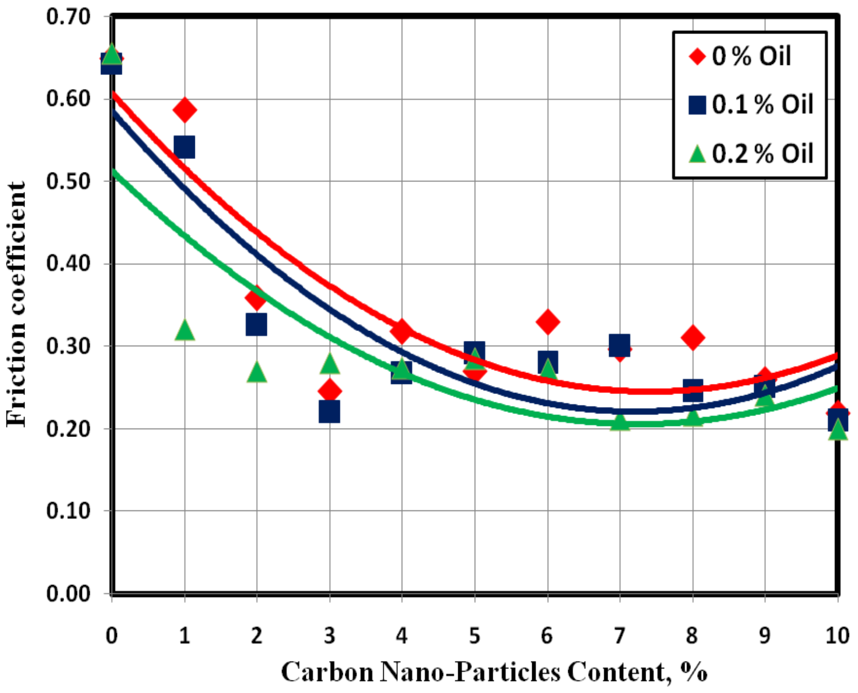

Fig. 4 Friction coefficient of epoxy test specimens filled by carbon nano-particles.

Epoxy composites filled by carbon nano-particles showed a decreasing trend in friction coefficient with increasing carbon content up to 7 wt. %, Fig. 4. The friction decrease was followed by slight increase as carbon nano-particles content increased. The friction increase may be related to the increase of material transferred into contact surface, while friction decrease may be attributed to the decreased ability of epoxy to adhere into the steel counterface due to the action of the oil that cover the counterface and prevented epoxy from adhering, Fig. 5. Besides, carbon nano-particles are good solid lubricant and effective in reducing friction coefficient.

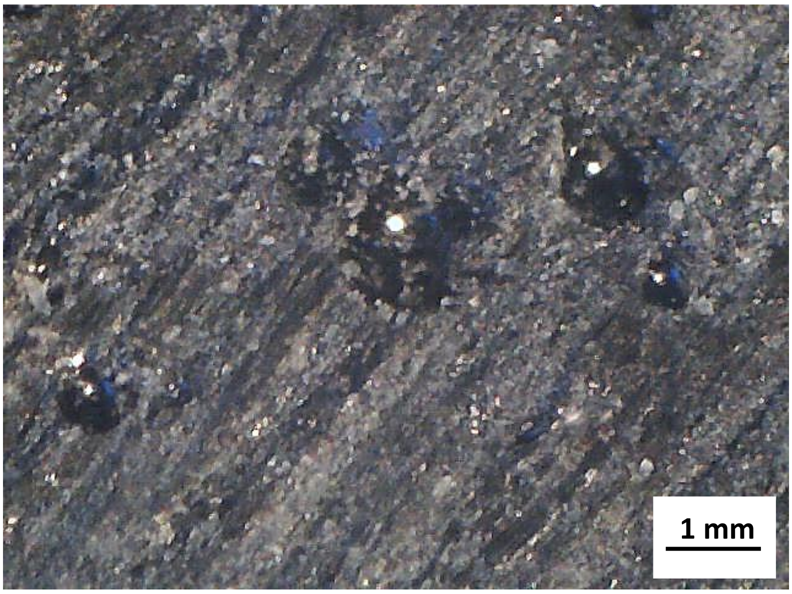

Fig. 5 The oil pockets in the sliding surface.

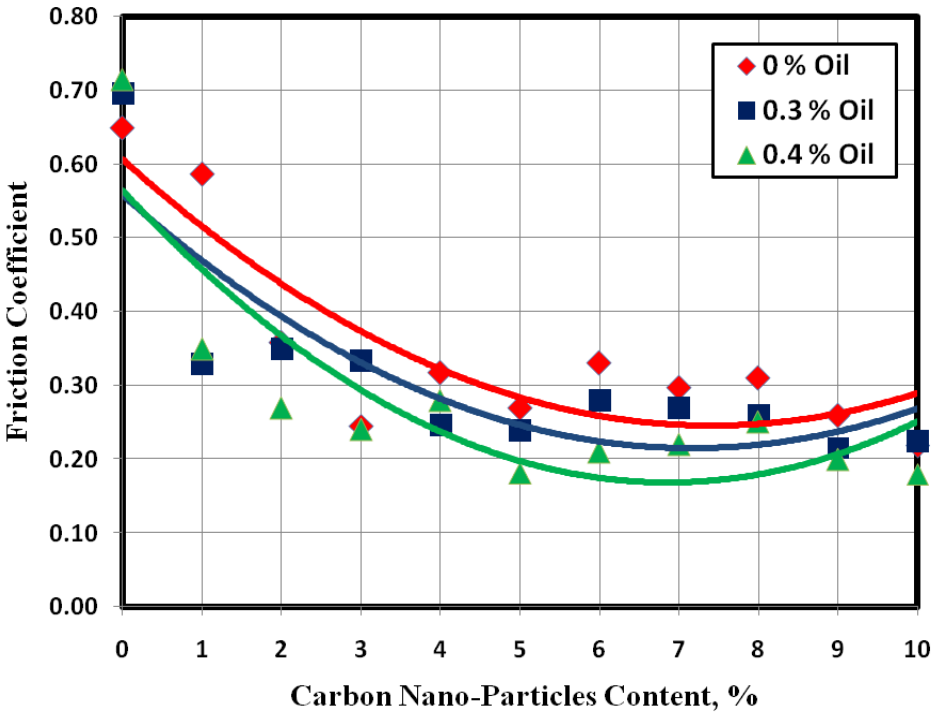

Fig. 6 Friction coefficient of epoxy test specimens filled by carbon nano-particles.

Filling epoxy composites by carbon nano-particles show decreased friction coefficient to minimum value at 7.0 wt. % carbon content then drastically increased with increasing carbon nano-particles content, Fig. 6. Increasing oil content up to 0.4 wt. % displayed remarkable decrease in friction values. This behavior related to the oil cover the contact area and reduces the ability of bonding between epoxy and steel surface. Besides, friction decrease might be produced from the stick carbon particles on the steel surface, Fig. 7. Friction increase may be caused by the weakness of test specimens with increasing carbon nano-particles content. The minimum value of friction coefficient (0.18) was observed at 7.0 wt. % carbon nano-particles and 0.4 % oil content.

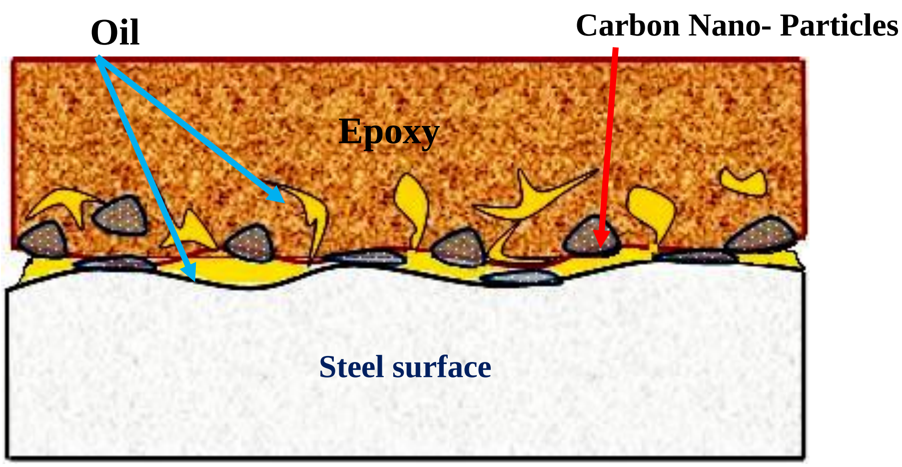

Fig. 7 Adherence of carbon nano-particles on the steel surface.

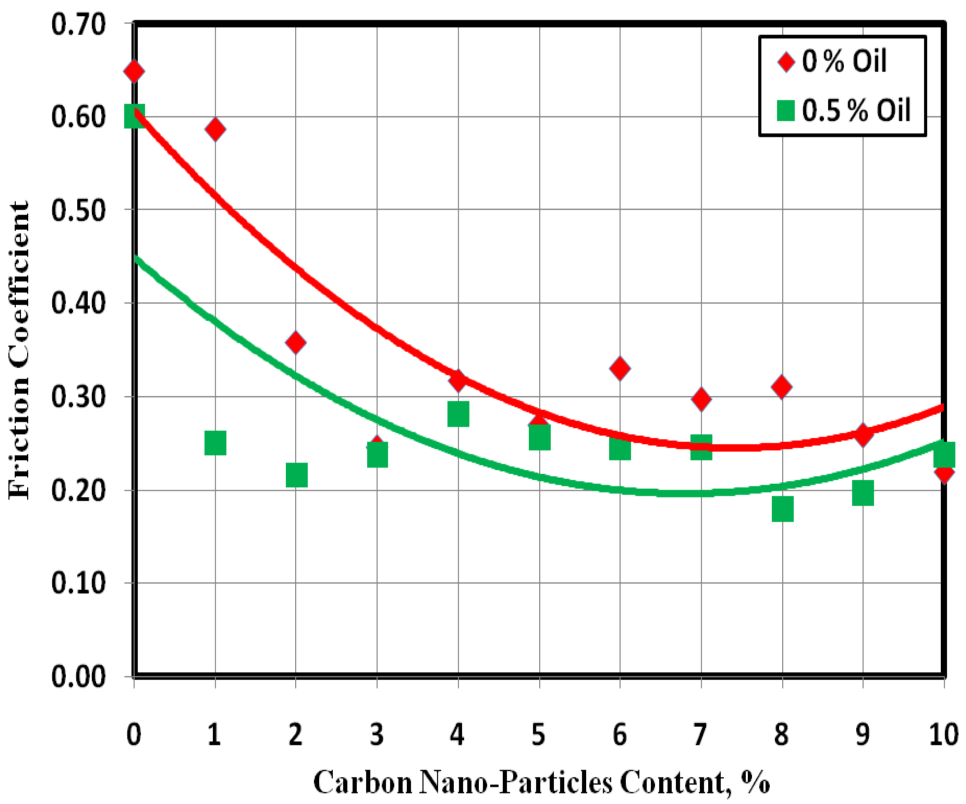

Fig. 8 Friction coefficient of epoxy test specimens filled by carbon nano-particles.

It was noticed that friction coefficient significantly decreased with increasing carbon nano-particles content, Fig. 8. Increase the oil content show more effect in reduction friction coefficient with concentration of carbon nano-particles up to 4 %. This behavior may be related to more homogeneous of test specimens, but increasing oil to 0.5% slightly increase in friction values with increasing carbon content over 4.0 wt. %.

Figure 9 show clearly demonstrates the effect of carbon nano-particles content on wear of epoxy composites filled by oil. The wear resistance of epoxy composites increased with increasing carbon nano-particles content. Presence of carbon would decrease epoxy transfer into steel surface so that the value of wear decreased. Increase oil content show significant effect on decreasing wear losses. This behavior may be related to the oil cover the contact surface and prevent bonding between epoxy and steel surface.

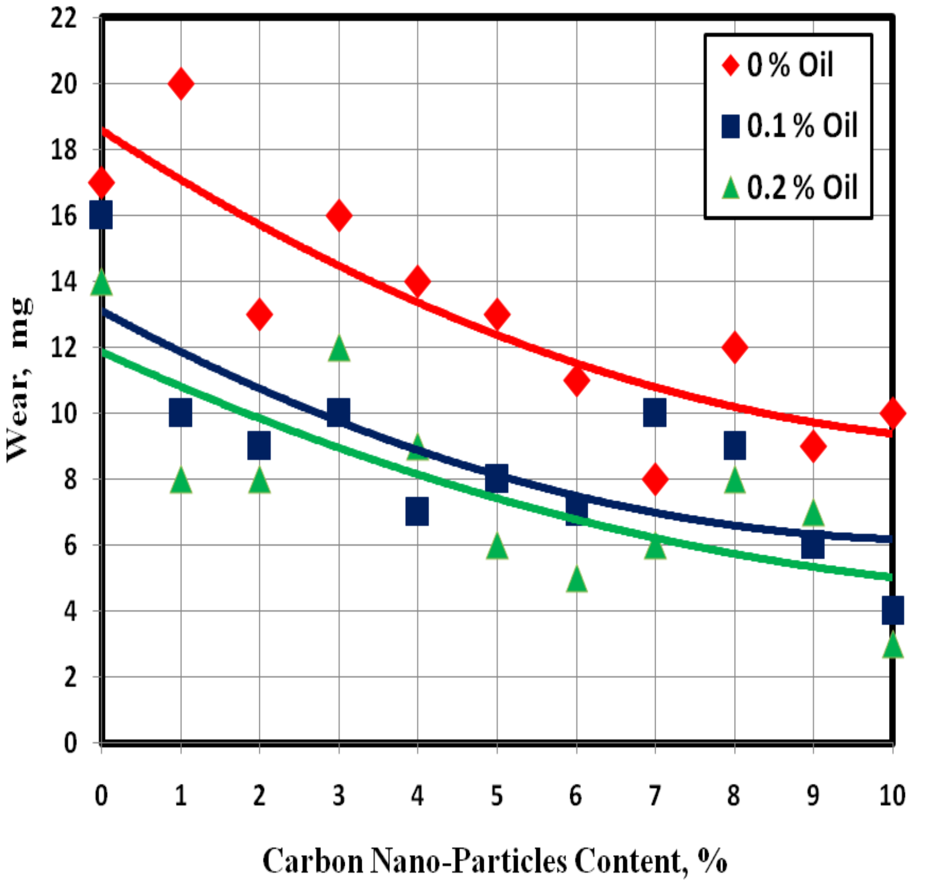

Fig. 9 Wear of epoxy test specimens filled by carbon nano-particles.

Slightly increasing in wear values observes with increasing oil content, Fig. 10. The wear losses increase with increasing oil content, because the high percentage of oil lead to weak the specimens and loss the carbon particles from test specimens. In presence of increasing carbon nano-particles content the wear losses decrease. This behavior may be related to the carbon particles forming a protective wear layer between epoxy and steel surface, Fig. 11. The minimum wear value was observed at epoxy test specimens filled by 10 wt. % carbon nano-particles and 0.3 wt. % oil content.

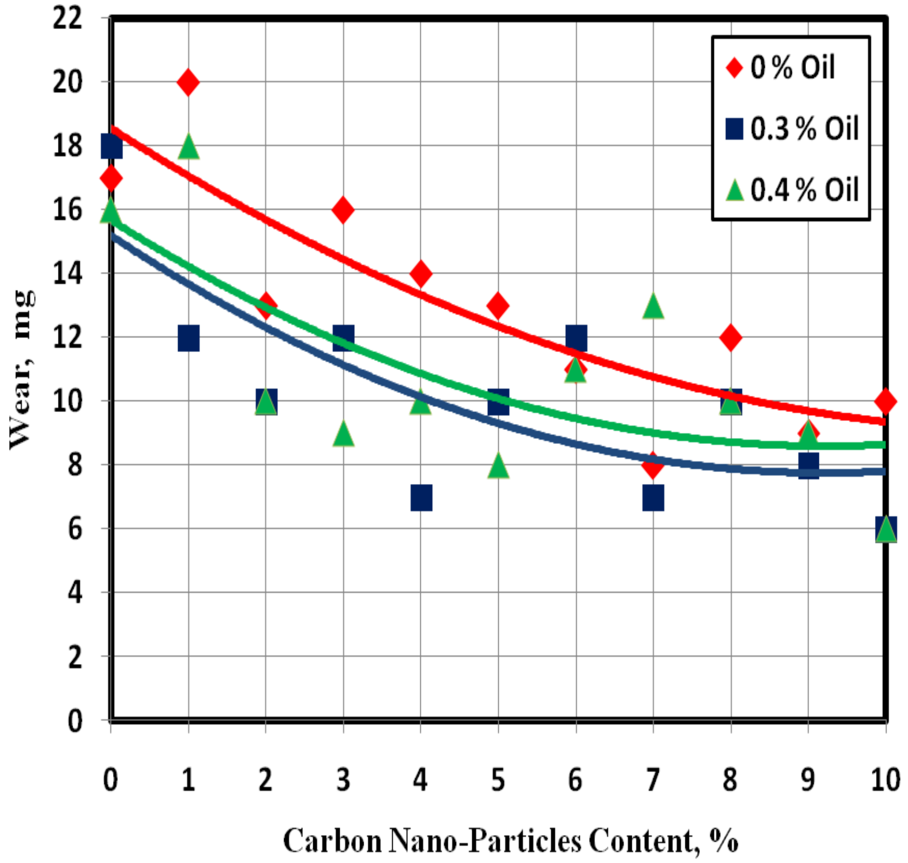

Fig. 10 Wear of epoxy test specimens filled by carbon nano-particles.

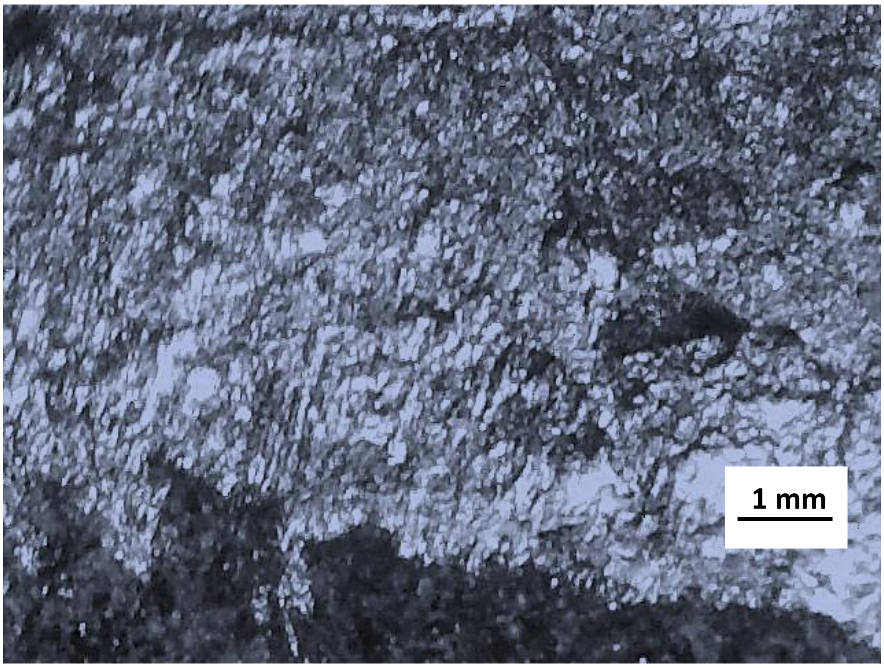

Fig. 11 The carbon particles forming a protective layer between epoxy and steel surface

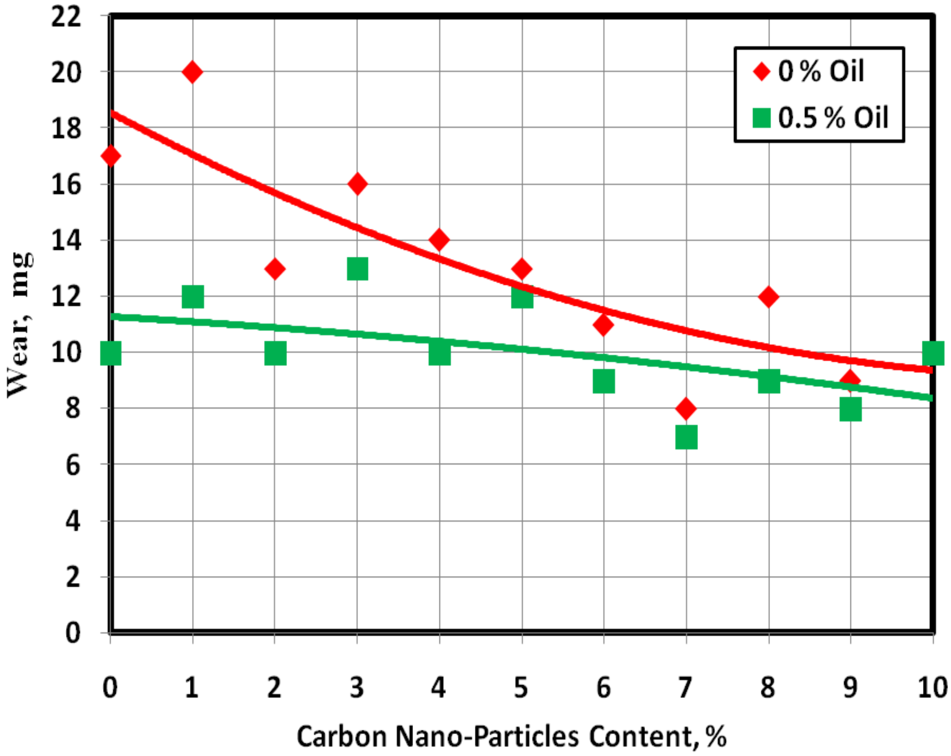

Fig. 12 Wear of epoxy test specimens filled by carbon nano-particles.

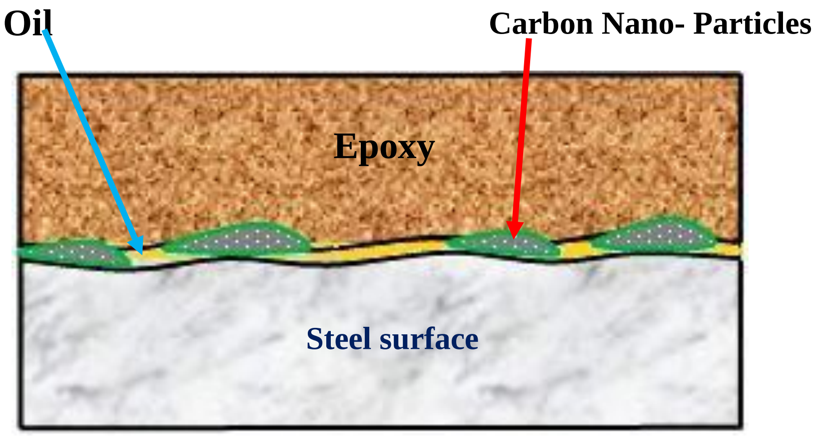

Fig. 13 Carbon particles deformed on steel surface and decreasing the contact between epoxy and steel surface.

Fig. 12 indicates that the wear decreased further as carbon content increased. Carbon particles play the effective role in reducing the bonding between sliding surface, this behavior based on the carbon used as solid lubricant in industrial applications, Fig. 13. Increasing oil content to 0.5 % show decreased in wear values with small percentage of carbon particles up to 3%. Slightly increasing in wear values was observed with increasing carbon particles and oil content. This behavior may be related to the non-homogeneous of test specimens and weak bonding between epoxy and carbon this behavior lead to separate the particles from test specimens.

CONCLUSIONS

1. The addition of carbon nano-particles to epoxy enhanced the wear resistance and reduces the friction coefficient.

2. The minimum value of friction coefficient (0.18) was observed at 7 % carbon nano-particles and 0.4 % oil content.

3. The wear resistance can be increase for epoxy composite by increasing carbon nano-particles up to 10% and 0.3% oil.

4. Increase of oil content decreased the bonding between epoxy and steel surface and reduce friction coefficient and wear losses.

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