

Effect of Molybdenum Disulfide Nano-particles on Dry Sliding Behavior of Carbon Fiber Reinforced Epoxy

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ABSTRACT

Carbon fiber reinforced polymers shows a rapidly increasing trend toward the replacement process of conventional materials by composites at numerous field applications ranging from house appliances to huge industries, because of its good mechanical, thermal and chemical properties. Carbon Reinforced epoxy composites recommended as an engineering material for a lot of tribological applications. In the present work molybdenum disulfide (MoS₂) Nano-particles were used as filling material for enhancing wear resistance and modify the frictional behavior of carbon fiber reinforced epoxy. Proposed composites were tested under dry sliding conditions for different sliding distances against steel counter-face by means of pin-on-disc tribometer. Results shows that; molybdenum disulfide nano powder remarkably reduce friction coefficient of epoxy composites. Beside; using of carbon fiber reinforcement improve wear resistance of proposed epoxy composites. The best combination obtained from carbon fiber reinforced epoxy with 30 % MoS₂ and 10 % carbon fiber for long sliding durations.

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1. INTRODUCTION

Fiber-reinforced polymer composites have been reasonably proposed for many industrial implementations such as marine's components, automotive parts, aerospace, and infrastructure. For its spread availability, low weight, flexible in manufacturing and excellent mechanical properties; polymers and polymer composites are being increasingly utilized for more and more engineering applications. At the expense of

useful properties of fiber reinforced polymers, they are used predominately in automotive, aircraft industries and manufacturing of spaceships and sea vehicles. Natural Fiber Reinforcement Polymeric Composites (NFRPC) used in the recent days in wide range of industrial applications. For its good environmental properties and availability, natural fibers and natural additives used as reinforcing material for most of polymeric composites. It was concluded that use of carbon

fiber decreases friction coefficient of polymer composites. The desired properties and application of the reinforcing phase detect the type of reinforcement in a polymer resin [1-8]. Glass and aramid fibers were preferred as reinforcement medium in polymer matrix composite sliding against steel for wear resistance applications. But polymer composites reinforced with glass fiber or aramid fiber shows affected behavior by some factors like fiber type, content, shape size, and loading direction, also matrix composition and conditions of testing such as load, speed, humidity, and temperature, as well as sliding conditions [9]. Different researchers have predicted that the attendance of secondary fillers such as Graphite rise wear resistance of composite during dry sliding. It is found that the wear initially controlled by the removal of graphite which acts as a self-lubricating material due to less friction between the mat layer and rotating disc. But with increases of contact pressure and sliding speed, the matrix material is well spread and the graphite in the powder form has covered the surface which improves its tribological properties [10]. Many different polymers and polymer composites are used for engineering applications in which friction and wear are critical issues. Epoxy resins with its corresponding curing agents were recommended as products in protective coatings, adhesives, structural components etc. This is mainly because of their suitable mechanical properties, excellent chemical resistance, good wettability, and electrical characteristics. Beside this epoxy resins can be used in many structural applications when reinforced with high strength fibers. For tribological applications, resins have low friction coefficients and low wear rate [11]. Epoxy resins-matrix phase of epoxy composites- have many advantages in comparison with other thermoplastics or thermoset polymers like little shrinkage while curing, cheaper in cost, good mechanical behavior, resist moisture and chemicals, good adhesion and corrosion resistance [12-15] Carbon fiber reinforced epoxy composites provide desirable properties for engineering applications, high specific strength, high specific stiffness, and good fatigue tolerance which support these composites to be used for military industry and manufacturing of aircraft structures [16]. Also, epoxy composites reinforced with carbon fiber allows for a combination of design principles and

manufacturing processes with preferred mechanical and physical characteristics. In spite of these advantages, there is some worry about the long-term durability of these materials under changing environmental conditions [17]. As a result of growing environmental issues, waste elimination and reduce of non-renewable resources, there is a huge interest in developing polymers from renewable resources in industrial applications [18-23]. For gears as an application of polymers and polymer composites, due to their low cost, simple for manufacturing, low weight and less noisy in operation than metal gears [24]. Besides, they can be self-lubricated, a replacement for metal gears in specific applications, like printers, kitchen electronics, and utilities, as well as electric vehicles [25]. On the other hand, there are some parameters can affect the production or performance of polymer/polymer composite parts, such as thermal effect and wear of material, they still under investigation [26-30]. In other words, mechanical and tribological properties of polymer products are significantly affected by thermal effects than metals [31,32]. Therefore, a lot of research works try to measure wear rate and the surface temperature during running [33-41]. The present work concerned with the investigation of the tribological behavior of carbon fiber reinforced epoxy under dry sliding conditions and for different sliding times with the presence of MoS₂ as filling nanoparticles.

2. MATERIALS AND METHOD

Epoxy resins (Envirotex Lite® glycidyl epoxy resin) used as a matrix for the proposed composites with its corresponding amin-based hardener in ratio 1:1. Carbone fiber- the reinforcement- (3K, 2x2 twill weave carbon fiber, 3*10⁻⁴ m thick. 4.3*10⁴ MPa tensile strength and 193 g/m² weight) in different ratios 5, 10 and 15 %. As well as nanoparticles of MoS₂ (up to 300 nm particle size) as friction performance modifier in ratios up to 50 % of the composites weight.

2.1 Preparing of test specimens

A rectangular test specimen was prepared through rectangular mold 30 mm x 10 mm x 10 mm. Polymer resin mixed with its hardener in the suitable ratio; then MoS₂ added to

mixture in the proposed ratios and well mixed using straight side steer for two minutes. Mixed compound cured into rectangular mold. Carbon fiber was cut in rectangular layers with the same dimensions of the test sample and carefully impregnated into the mold in different ratios. Each specimen left for 72 hours under 70° for complete solidification. After full solidification of the test sample, it cut into required size (20x3x5 mm) and smoothed by emery paper; grit size (600) then cleaned by alcohol to be ready for the test. For the purpose of accomplishment of the tribological measurements; in form of friction coefficient and wear rate by means of pin -on-disk tribometer.

2.2 Tribological test procedure

After preparing of the test specimen in form of a rectangular shape it loaded to the rotating steel disk under contact pressure of 0.47 N/mm^2 for sliding speed 23 mm/s . The friction force which determined as a result of contact between the rotating disk and polymer composites test sample measured by means of the load cell and displayed in newtons on an attached digital screen. Friction coefficients measured for different sliding distance varied from 0.5 m to 15 m. Wear of carbon reinforced epoxy filled with molybdenum disulfide measured as the rate of weight loss of specimen under dry sliding for 15 m sliding distance. Each test repeated three times and average result recorded.

3. RESULTS

3.1 Epoxy free of carbon fiber

Friction coefficient of epoxy filled with Molybdenum disulfide presented in Fig. 1 that explain the relation between coefficients of friction of epoxy composite and MoS_2 content under different sliding distances. It seems that the presence of MoS_2 in epoxy remarkably reduces the friction coefficient of epoxy composite from 0.4 to about 0.15 for epoxy filled with 30 % Molybdenum disulfide, this reduction in friction coefficient may be as a result of good lubricating conditions of MoS_2 powder that form thin film on the contact area and behave as lubricant layer specially under long sliding distance.

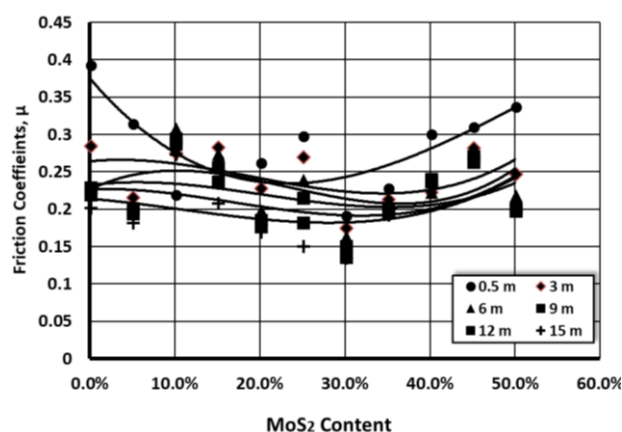


Fig. 1. Effect of MoS_2 and sliding distance on friction coefficient of epoxy.

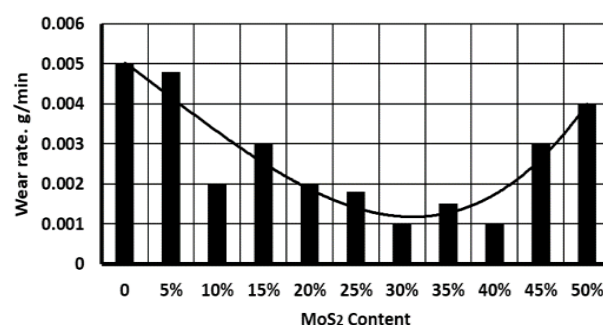


Fig. 2. Effect of MoS_2 on wear rate of epoxy.

Wear rate of epoxy filled with molybdenum disulfide under dry sliding for 15m shown in Fig. 2, rate of wear decreased from 0.005 g/min. for free epoxy to about 0.00185 g/min. as MoS_2 content increased up to 30 %. Unexpectedly extra increases of MoS_2 content more than 30 % increase the friction coefficient and material loss (wear rate) of epoxy composites which seems that there is weak bonding between composite contents that form hard particles on the matting surfaces that behave as third body and increase the friction coefficient and wear of epoxy composite.

3.2 Reinforced epoxy composites

Carbon fiber which has good mechanical and tribological properties as reinforcing material for polymer composites, carbon fiber expected to enhancement mechanical strength of epoxy composite as well as modify frictional behavior and increase wear resistance of proposed composites. Figures 3-5 shows the friction coefficients of epoxy composites in the presence of carbon fiber reinforcement. Unfortunately, and to the opposite expected results; increase of carbon fiber increases the friction coefficients of Molybdenum disulfide filled epoxy, this behavior

may be result from the nature of carbon fiber which act as abrasive points on the contact surface with counter-face, that increase the friction coefficient of epoxy composites. Besides, slightly increases of friction coefficient with increase of MoS₂ content specially under low fiber content; 5 % and low contact durations. There is little reduction in friction coefficients of epoxy composite reinforced with 10 % and 15 % carbon fiber as MoS₂ content increases to 30 %.

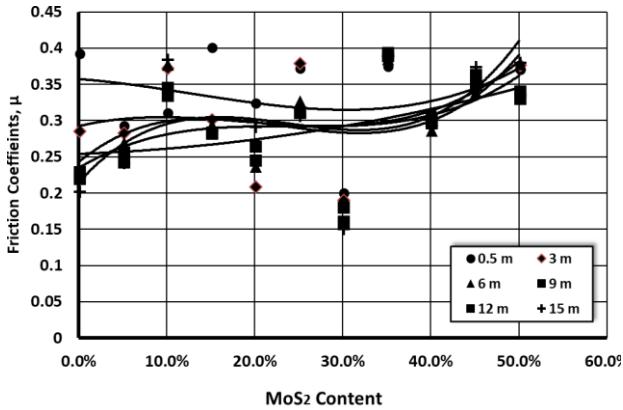


Fig. 3. Effect of MoS₂ and sliding distance on friction coefficient of epoxy composite reinforced by 5 % carbon fiber.

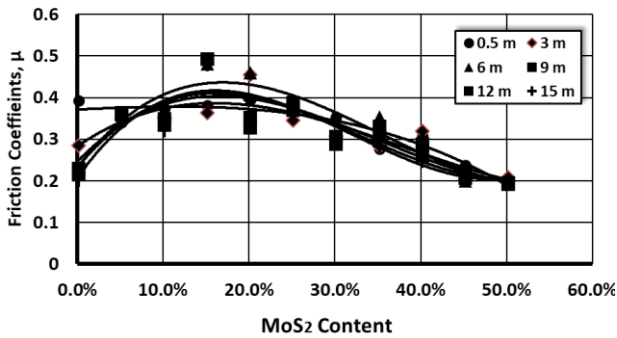


Fig. 4. Effect of MoS₂ and sliding distance on friction coefficient of epoxy composite reinforced by 10 % carbon fiber.

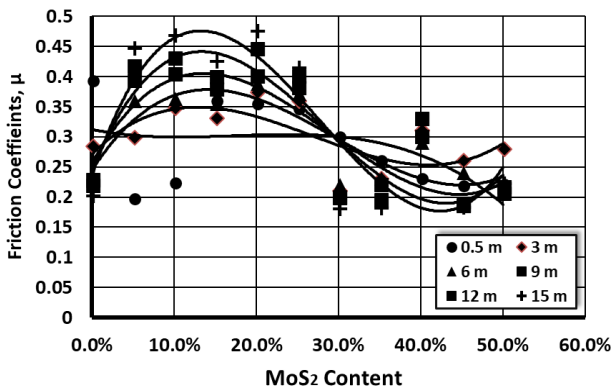


Fig. 5. Effect of MoS₂ and sliding distance on friction coefficient of epoxy composite reinforced by 15 % carbon fiber.

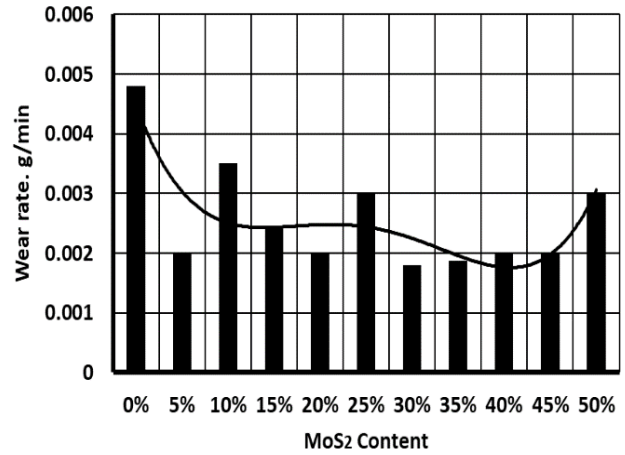


Fig. 6. Effect of MoS₂ on wear rate of epoxy composite reinforced by 5 % carbon fiber.

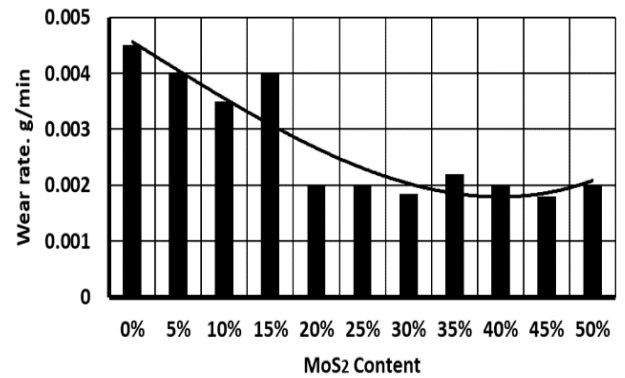


Fig. 7. Effect of MoS₂ on wear rate of epoxy composite reinforced by 10 % carbon fiber.

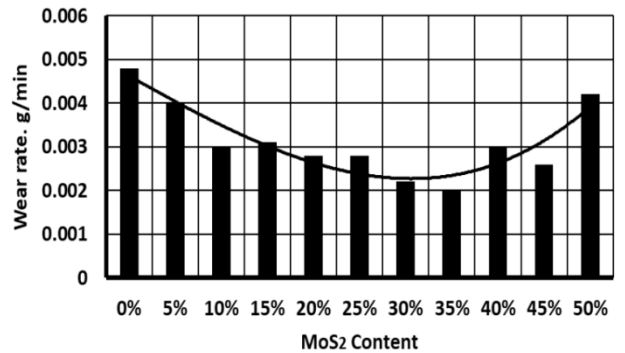


Fig. 8. Effect of MoS₂ on wear rate of epoxy composite reinforced by 15 % carbon fiber.

Wear rates of epoxy composites filled with MoS₂ and reinforced with carbon fiber under long sliding distance 15 m have been presented in Figs. 6-8. There is remarkably reduction in wear rate with the presence of carbon fiber, rate of wear decreased to about 0.004 g/min. for epoxy free of fillers as fiber content increases to 10 %, also increase of MoS₂ content to 30 % significantly reduce the wear rate of proposed composite to less than 0.002 g/min.

4. CONCLUSION

As mentioned in results it can conclude that:

1. Molybdenum disulfide improve tribological properties of epoxy composites,
2. Friction coefficient of epoxy filled Molybdenum disulfide increased with increase of carbon fiber reinforcement,
3. Friction coefficient of epoxy composite slightly reduced under long sliding distances,
4. Used of carbon fiber enhance wear resistance of epoxy composites,
5. The best results among proposed composite reached at 10 % carbon fiber and 30% MoS₂ that shows low friction coefficient and high wear resistance.

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