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Triboelectrification of Carbon Fiber Reinforced Epoxy Composites

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ABSTRACT

Triboelectrification phenomenon recently used (exploited) to be a source of clean energy. The generated amount of energy from rubbing or contact between insulators can be used for self-charged devices, wearable devices, biomedical sensors and devices and so on. The amount of power that produced by this phenomenon depends on several factors. Some factors related the rubbing materials and others related to contact mechanism. The present work investigates the effect of composition of epoxy composites reinforced by carbon fiber as well as the contact mechanism on the generated amount of electricity as a result of contact and sliding on Kapton film. Effect of metallic additives, beside; contact frequency for contact-separation mode as well as sliding velocity for lateral sliding mode.

KEYWORDS

Carbon fiber Epoxy Composites, Triboelectrification, natural fillers, Triboelectric-generator TEG, contact-separation mode, lateral sliding mode.

INTRODUCTION

Triboelectricity of nonconductors material employed by *Wang's* team since 2012, they proposed a new generators for electrical energy called Triboelectric Generators TEG that improved to Triboelectric Nano-Generators TENG. These generators based on the Triboelectrification effect between rubbing or contact materials, that generate an amount of electric power on the surfaces of contact pair of nonconductive materials. The amount of generated energy depends on several factors; type of contact materials, location of contact materials in triboelectric series, contact mechanism, contact load, sliding velocity, contact frequency and other environmental factors are some of these factors that affect the generated power. Polymer composites used recently as a promise alternative for conventional materials in a lot of industrial applications because of its good mechanical and physical properties. Natural fillers as well as metallic additives were investigated as tribological performance enhancer of polymeric composites. It was concluded that the friction coefficient and wear rates of HDPE and PP composites decrease with increasing copper content, [1-10], agricultural wastes have a significant effect on the friction coefficient and wear rates of polyester composites. Polyester composites reinforced with palm fronds were recommended as high friction and low wear rate material for industrial applications such as brake pads.

Date palm seeds were proposed as a natural fillers for polyester composites, it was found that there is a significant effect of the applied load and sliding velocity on the wear rate of polyester composite filled with date seed, polyester composites filled with Corn Straw Powder (CSP) or Jasmine Leaves Powder (JLP) proposed as new engineering materials with improved mechanical and frictional behavior. Static charges that generates as a result of rubbing between dissimilar surfaces were investigated in more than research paper, the electric power comes from this phenomenon (Triboelectrification) was proposed to be used for self-charging devices and wearable devices in form of triboelectric generators or triboelectric Nano generators. Using of Al mesh as a reinforcement phase in epoxy composites significantly affect the ESC generated on the composite surface and adhesion during sliding on rubber. Beside the composition of rubbing materials; the electro static charges also depends on the substrate layer that act as an electrode in triboelectric generators, *Ali* et al. conclude that that copper substrate represented the lowest ESC values, while PP substrate displayed the highest values. Besides, grounding the metallic substrate caused significant ESC reduction. PE fibers blended by PMMA yarns drastically decreased ESC regardless the material of the substrate. In addition to that, it was observed that increasing the ratio of PA yarns blending PE turf decreased ESC, while PA textiles in form of ribbons experienced more reduction in ESC because the flexibility of the turf enables for extra deformation of turf leading to an increase in the contact area. Finally, the value of ESC can be minimized by the control of the content of PA textile [11-15]. It was confirmed that the value of ESC proportionally increased with the increase of the magnetism of the metallic films [16-19]. It was concluded that, a small amount of mechanical movement between insulating surfaces can generate an electric power that can be used in low consumption devices or sensors. Increase of contact frequency or sliding velocity can increases the output Dc voltage of Kapton-PTFE TEG. It was recommended that the output electricity can be increased be using multiple layers of Kapton- PTFE TEG, [20]. Wang et al. expected that triboelectric is a dangerous effect into industry due to the fact the electrostatic charge could lead to ignition, dirt explosions, dielectric breakdown, electronic damage, etc. But of some other hand electrostatic charges incorporate a capacitive energy system. It was concluded that triboelectric generators (TEGs) have the manageable of harvesting electricity from human activities, rotating tires, ocean waves, mechanical vibration and more, with top notch purposes in self-powered structures for personal electronics, environmental monitoring, clinical science and even large-scale power, [21-30]. The triboelectric action also proposed as a novel phenomenon to help in medical care team's protection during COVID-19 pandemic by means of suitable selection of personal protection equipment PPE materials that helps in repel viruses away based on the surface charge of viruses. It was recommended that for safety goggles that used to provide personal protection from COVID-19 to be made from negatively charged materials that lies in the bottom side of triboelectric series, [31-35]. The present work investigate the effect of composition of epoxy composites reinforced by carbon fiber as well as the contact mechanism on the generated amount of electricity as a result of contact and sliding on Kapton film.

EXPERIMENTAL

Materials and Test Specimens

Epoxy resin C21H25ClO5 (Easy Cast-Clear Epoxy) with its corresponding hardener 'Tetrahydromethylphthalic anhydride' was used to prepare the matrix mixture of proposed

composite, the suitable ratio of resin to hardener is 1:1 as recommended from the supplier. Carbon fiber in form of plain textile used as reinforcement by ratio of 15% as well as other fillers in form of nanoparticles (up to 100 nm) of sunflower husk seeds added to the mixture in ratio of 10% from the composite volume. The epoxy-hardener mixture and copper filler were blended by means of electrical blender to provide good distribution of metal particulates inside the test specimen. After well mixing of resin and powder, test specimens produced by hand-layup technique on carbon fiber that already adhered on a thin film of aluminum (as an electrode) which adhered on rectangular wooden substrate (20 mm x 10 mm) to make a single layer (2 mm thickness) of triboelectric generator TEG. The other layer (2 mm thickness) of TEG composed of Kapton film placed on a thin layer of an aluminum electrode.

Measurements

After full drying of epoxy composites for two days, test specimens will subjected to contact with Kapton film in two modes; contact - separation and lateral sliding under different conditions of dry contact, different sliding speeds and contact frequency. Surface charges that generated because of rubbing action between the two dissimilar layers will be detected by means of surface DC voltmeter and Oscilloscope respectively. The effect of rubbing conditions as well as composites contents on the amount of generated charges will be discussed.

RESULTS AND DISCUSSION

Figures 1, 2 shows the effect of additives on the generated electricity of epoxy composites, as shown in this figure; presence of sunflower husk seeds powder increases the amount of static charge of epoxy composites sliding on Kapton under low speed and 2N applied load. But; under high loads 10 N and low sliding speed the electricity increases which may be a result of high contact between matting surfaces.

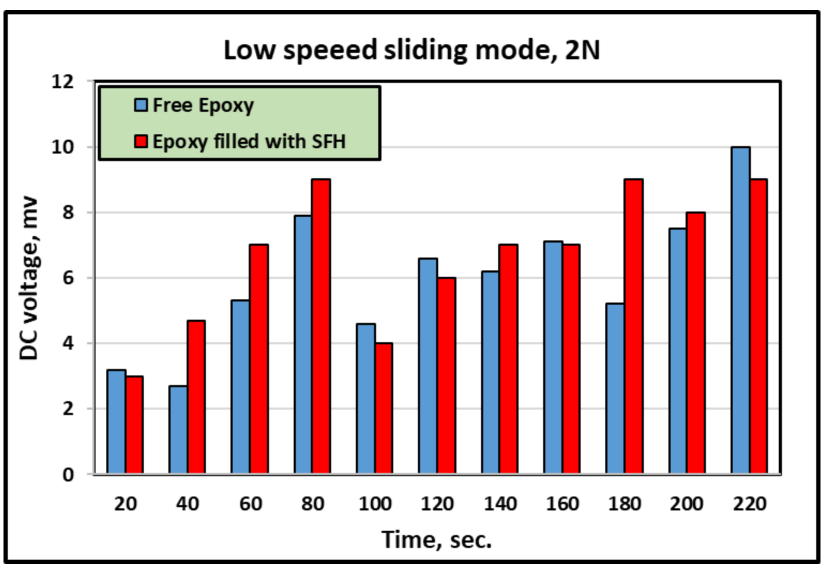

Fig. 1 Triboelectric discharge of epoxy composites under low sliding speed and low applied loads.

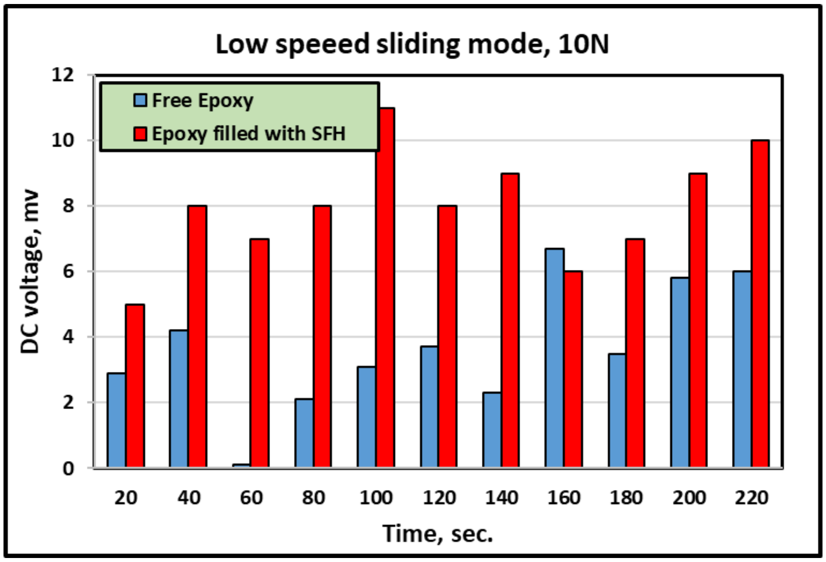

Fig. 2 Triboelectric discharge of epoxy composites under low sliding speed and high applied loads.

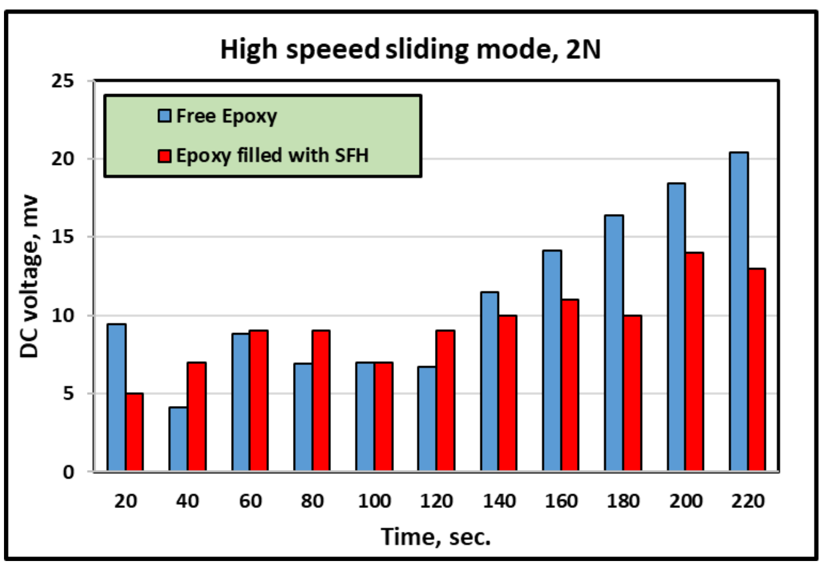

Fig. 3 Triboelectric discharge of epoxy composites under high sliding speed and low applied loads.

Sliding of composites under high speed increases the amount of generated electricity of epoxy composites free of additives under low and high loads.

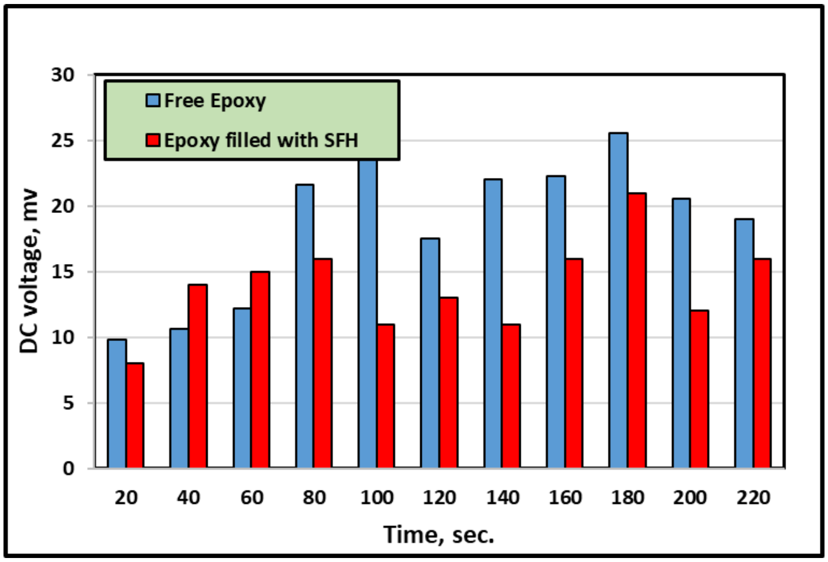

Fig. 4 Triboelectric discharge of epoxy composites under high sliding speed and low applied loads.

Figs. 5-8 shows the effect of contact separation frequency and applied loads on the generated charges of epoxy composites and Kapton layers. As shown in figures under low and high contact frequency and low loads the presence of natural additives increases the generated charge of contact composites.

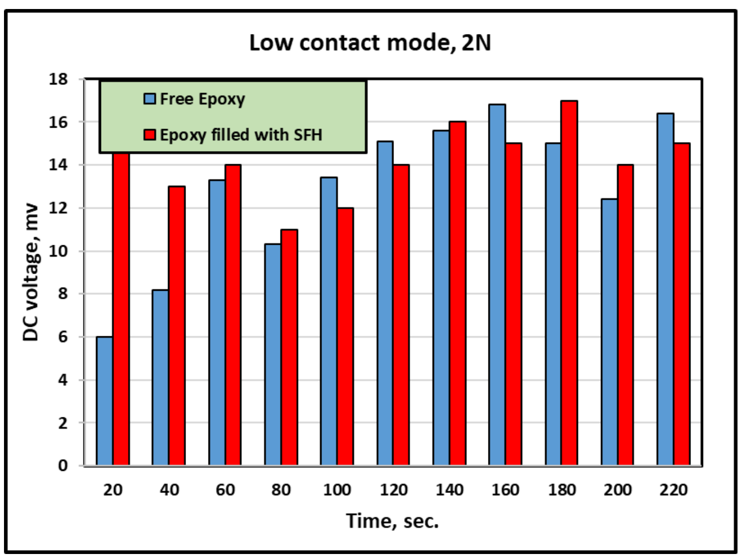

Fig. 5 Triboelectric discharge of epoxy composites under low contact freq, and low applied loads.

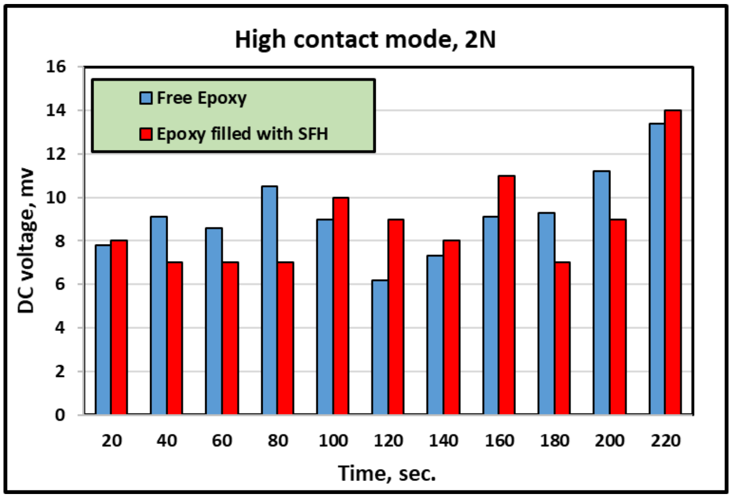

Fig. 6 Triboelectric discharge of epoxy composites under high contact freq, and low applied loads.

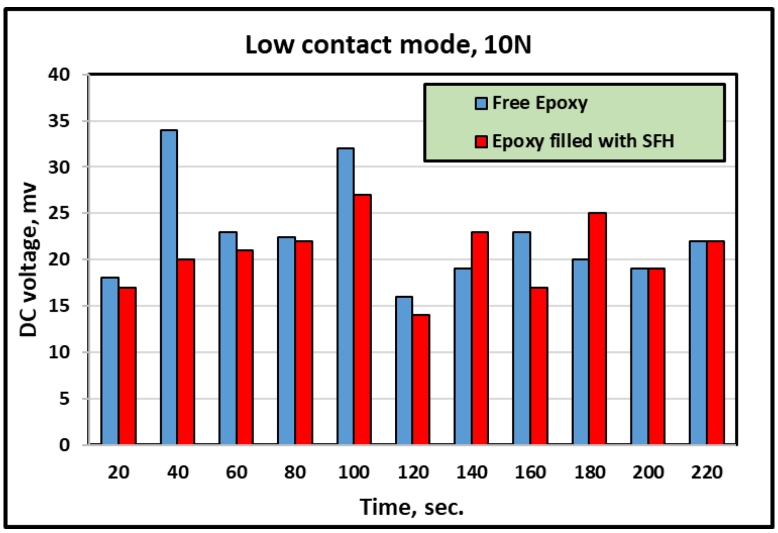

Fig. 7 Triboelectric discharge of epoxy composites under low contact freq, and high applied loads.

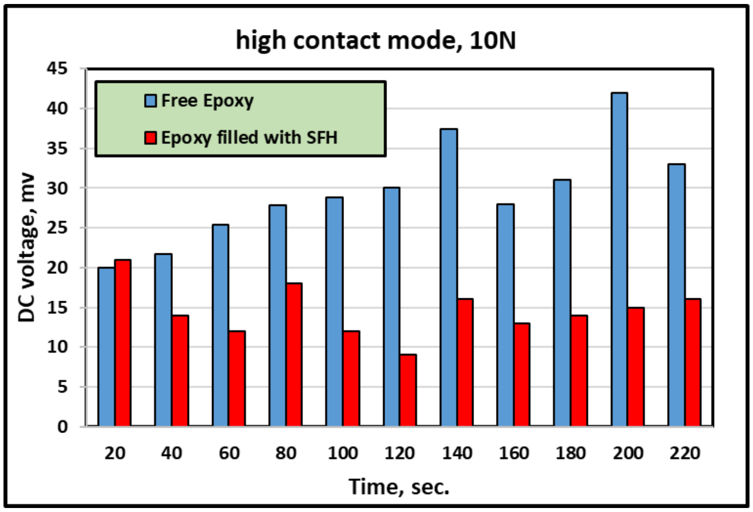

Fig. 8 Triboelectric discharge of epoxy composites under high contact freq, and high applied loads.

As the applied loads increases the presence of sunflower husk seeds shows little effect on the triboelectric charges under low and high contact frequency.

CONCLUSIONS

From the results of the experimental it can be concluded that:

1- **Epoxy composites reinforced with carbon fiber and filled with natural fillers can be used as an electrode layer in triboelectricgenertors TEG.**
2- **Using of sunflower husk seeds powder increases the amount of generated charge**
3- **Sliding under high contact pressure increases the amount of charge generated between sliding layers**
4- **The amount of triboelectric energy that generated by means of contact-separation mode exceeds the amount of charge generated from sliding mode.**

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