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TRIBOELECTRIFICATION OF CARBON FIBER REINFORCED EPOXY COMPOSITES

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ABSTRACT
The effect of triboelectric discharge or triboelectrification of rubbing materials recently attracting the attention of scientists to be used as a source of clean energy. There is an amount of electrical energy produced by means of employing the triboelectric effect of sliding between nonconductive layers which known as triboelectric generators TEGs. There are several factors affecting the generated electricity from TEG ranged from the contact mode, dielectric layers to electrode material and rubbing conditions. Wearable devices, sensors, energy storing devices are some examples of the applications of TEGs beside the gathering of clean and low-cost energy. This research paper concerns the investigation of the triboelectrification behavior of polymeric composites reinforced with carbon fiber. There are some additives that were suggested to improve the output electricity. Effect of contact mechanism as well as additive types and sliding conditions were examined. Lateral sliding and contact separation modes were employed for the proposed TEGs. The results show that; using of sunflower husk seeds powder increases the amount of generated charge, as well as sliding under high contact pressure increases the amount of charge generated between sliding layers.

KEYWORDS
Polymeric composites, natural additives, Triboelectric discharges, Triboelectric-generator TEG, contact-separation mode, lateral sliding mode.

INTRODUCTION
Wang's team has been exploring the triboelectric properties of non-conductive materials since 2012. They introduced a novel approach to generating electrical energy known as Triboelectric Generators (TEG), which has evolved into Triboelectric Nano-Generators (TENG). The functioning principle relies on the triboelectrification effect occurring between materials in contact or undergoing rubbing. This process generates electric power on the mating surfaces of non-conductive materials. The quantity of the electrical power that generated is influenced by various factors, including the materials based on the triboelectric series sorting,

the mode of connection or sliding between layers, external forces, contact or sliding frequency or speed, as well as some other factors related to the surrounding environment and working conditions. Recently, polymeric composites have emerged as a promising alternative to construct several types of triboelectric generators for energy harvesting applications due to their good mechanical and physical behaviors. A lot of research work proposed natural fillers and other additives to improve the tribological and triboelectric behavior of some polymeric composites. Friction coefficients, wear rate as well as electrostatic discharges of HDPE composites or PP composites were enhanced by means of some additives like copper powder [1-10].

Agricultural wastes also have a significant effect on the friction coefficient and wear rates of polyester composites. From the tribological point of view, polymeric composites show improved performance on the level of friction and wear resistance by adding some natural fillers, there were some additives as palm fronds, palm date seeds, corn straw, and jasmine leaves; increases the friction coefficient and wear resistance which preferred for applications such as flooring materials and brake pads materials. On the other hand, some natural additives reduce the friction coefficient and wear rate that preferred for bearing or sliders applications. For the purposes of energy collection, polymeric composites also record an advanced position among other traditional materials and working as good alternative for construction of triboelectric generators TEGs, several research efforts recently concerned with the studying of the performance of triboelectric generators and nano-generators made of polymeric materials.

Internet of things, wearing sensors, self-powered devices are some of many applications that are based on the principle of triboelectrification effect of insulating substances. W. Y. ali et al. proposed a triboelectric layer made of epoxy composites reinforced with an aluminum mesh, they were concluded that there is a significant effect on the generated charges at the surface of epoxy composites and adhesion during sliding on rubber. In addition to that, it was observed that for some applications the triboelectric effect is not preferred as in clothes or electronic chips manufacturing workstations which could lead to injuries or chip damage, for these reasons; increasing the amount of PA fiber in PE turf decreased the generated electrostatic charges [11-19]. It was concluded that, the electric energy generated by triboelectric generator consist of PTFE and Kapton dielectric layers can be improved by increases the contact-separation frequency or rubbing speed. Also for the same proposed TEG it was recommended that using of multiple layers of dielectric films will increases the output energy.[20]. The findings suggest that triboelectric generators (TEGs) offer the capability to harvest electricity from various sources, from human movements, car tires rotation, water waves, vibration and so on. They hold great potential for applications in self-powered structures, ranging from personal electronics and environmental monitoring to medical science and even large-scale power generation [21-30]. During the pandemic of COVID-19, there were more than one research publications concerned with the medical application of the triboelectric phenomenon. A safety goggles as an example of personal protection equipment were investigated for the purpose of proper selection of its material which

have the ability to decreases the viral loads by means of triboelectric effect of the goggle's material and the negative charge on the outer layer of virus. [31-35]. In the present research epoxy composites reinforced with carbon fiber were proposed to construct a single layer triboelectric generator (TEG) and studying the effect of natural fillers in form of sunflower husk seeds, rubbing conditions contact mechanism and frequency on the output voltage.

EXPERIMENTAL

Materials and Test Specimens

Test specimens consist of Epoxy polymer matrix, reinforced with 15 wt.% carbon fiber filled with 10 wt.% sunflower husk seeds nanoparticles (up to 100 nm). This mixture poured into rectangular mold to build up the proposed single layer triboelectric generator, a thin layer of aluminum film 0.5 mm thickness was placed at the bottom of the mold to form the electrode layer of the triboelectric generator. The formed layer of epoxy composite and aluminum film were cut into rectangular samples (20mm x 10mm x 2mm) to make a single layer of triboelectric generator TEG. To construct the second pole of proposed generator polyamide film that known commercially as Kapton was placed on a thin layer of an aluminum electrode.

Measurements

To perform the measurements that are required for evaluation of proposed TEG performance, epoxy composites layer will be subjected to contact for application of contact-separation mechanism or sliding for lateral sliding application with Kapton layer in the presence of an external load. High precession multimeter has been used to measure the output voltage from the triboelectric generator under different modes and conditions as well as the effect of filling material. Two values of sliding speed 10m/min and 20m/min, two values of applied loads 2N and 10 N, as well as 2Hz and 5Hz contact frequency were applied to perform the required measurements.

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.

Figure 3 shows the effect of increases of sliding velocity of lateral sliding triboelectric generator comprised of epoxy composites filled with sunflower husk seeds on the output voltage under low contact loads, as shown in this figure the generated electricity increases slightly with time for epoxy filled with natural filler, besides the electrical voltage of free epoxy shows high values with time under the same conditions. For the same TEG under high speed and high applied loads as shown in fig. 4 the output voltage increases with time for free epoxy than filled composites.

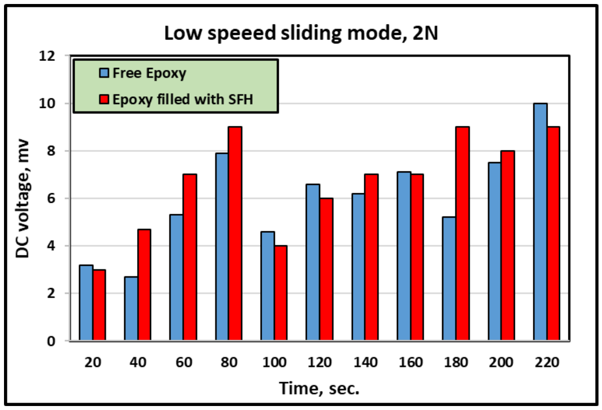

Fig. 1 Electric voltage generated by lateral sliding epoxy TEG under low speed and low applied load.

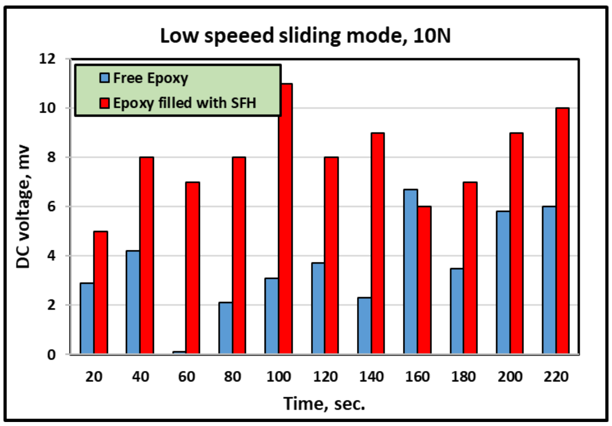

Fig. 2 Electric voltage generated by lateral sliding epoxy TEG under low speed and high applied load.

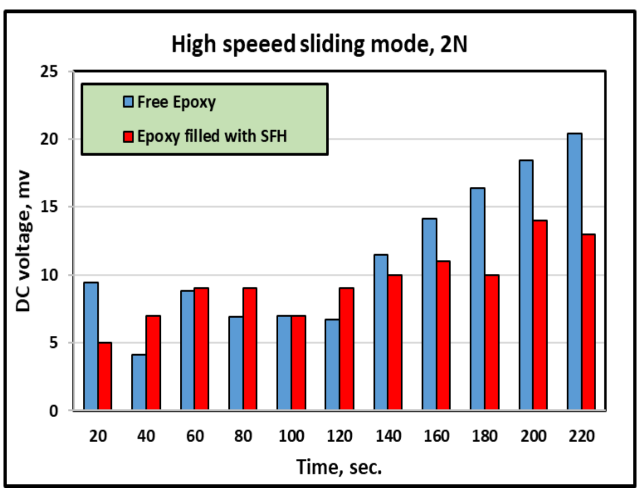

Fig. 3 Electric voltage generated by lateral sliding epoxy TEG under high speed and low applied load.

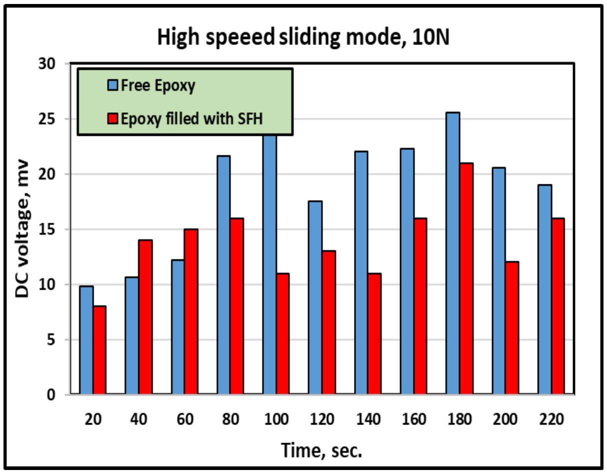

Fig. 4 Electric voltage generated by lateral sliding epoxy TEG under high speed and high applied load.

Sliding of composites under high speed increases the amount of generated electricity of epoxy composites free of additives under low and high loads. Figs. 5-8 show the effect of contact separation frequency and applied loads on the generated charges of epoxy composites and Kapton layers. As shown in the figures under low and high contact frequency and low loads the presence of natural additives increases the generated charge of contact composites. As the applied loads increase the presence of sunflower husk seeds shows little effect on the triboelectric charges under low and high contact frequency. He has got a mobile

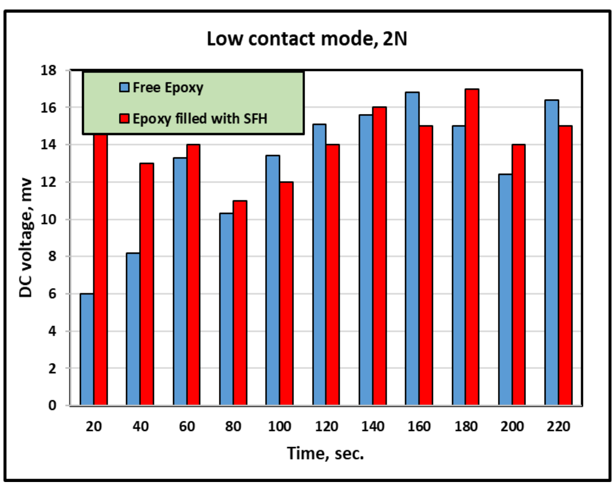

Fig.5 Electric voltage generated by contact-separation epoxy TEG under low contact frequency and low applied load.

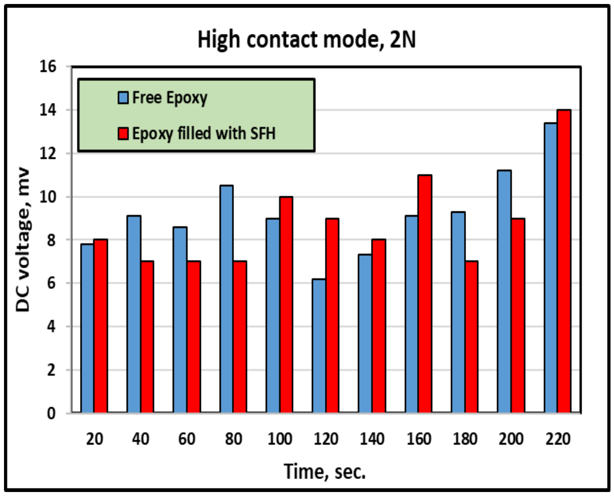

Fig.6 Electric voltage generated by contact-separation epoxy TEG under high contact frequency and low applied load.

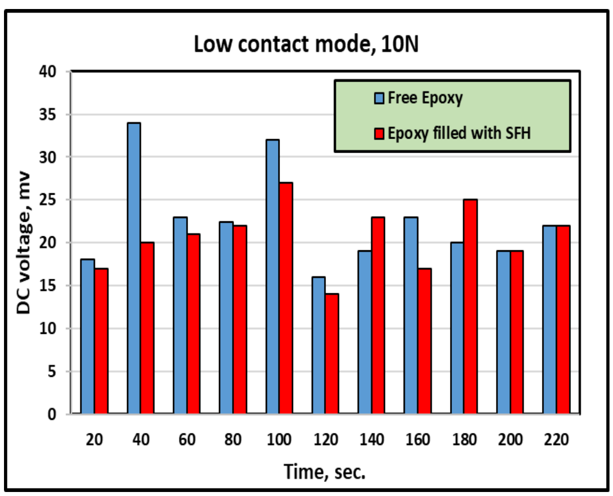

Fig. 7 Electric voltage generated by contact-separation epoxy TEG under low contact frequency and high applied load.

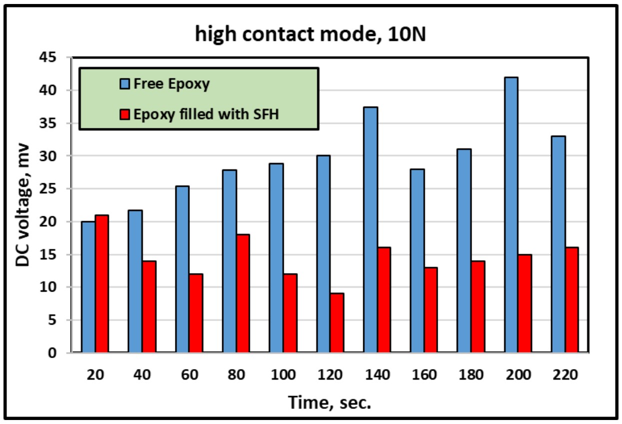

Fig. 8 Electric voltage generated by contact-separation epoxy TEG under high contact frequency and high applied load.

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 generated by means of contact-separation mode exceeds the amount of charge generated from sliding mode.

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