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INFLUENCE OF SURFACE ROUGHNESS ON THE OUTPUT VOLTAGE OF A TRIBOELECTRIC NANOGENERATOR

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ABSTRACT
Triboelectric nanogenerators (TENG) are becoming increasingly popular due to their wide range of uses, ranging from self-powered sensors to energy harvesters, they are devices that make use of the triboelectric effect in order to convert mechanical energy into electric energy. However, in order for them to be as effective as possible, complicated surface geometries are often used. The present study investigates a cheap method of obtaining desirable surfaces for use in TENG, using commercial emery paper to roughen one of their two surfaces.

It was found that increasing the grit and thus decreasing the particle size of the emery paper used in roughening the surface increased the output open circuit voltage of the triboelectric nanogenerator. It is concluded that emery paper works as a cheap method of roughening one of the two surfaces of a TENG, and increasing the number of contacting asperities leading to the increase of electrostatic charge. It was found that as the value of the applied load increases, the output voltage increases, due to the increase of the actual contact area of the TENG.

KEYWORDS
Surface roughness, emery paper, kapton, polyamide, voltage, triboelectric nanogenerator.

INTRODUCTION
Triboelectrification is the phenomena is that when two materials come into contact with each another, charges are transferred from one material to the other, [1 - 4]. Despite triboelectrification was observed very early in human history, it is still poorly understood, with electron and ion transfer theories being popular theories, [5].

To determine the intensity and sign of the induced surface voltage resulting from triboelectrification, the triboelectric series was developed, [6 - 8], it is a series that ranks materials by their likelihood of obtaining a positive charge when they come into contact with another material, kapton is one of the materials which is located near the bottom of the triboelectric series, thus has a high likelihood of obtaining a negative charge, [9], while polyamide (PA) is one of the materials which are located near the top of the triboelectric series, [10].

This phenomenon of triboelectrification can be utilized to produce a device called the Triboelectric Nanogenerator (TENG), [11-18], the TENG is made of two dielectric materials which are on opposite sides of the triboelectric series connected to electrodes. When the two dielectric surfaces come into contact with one another, they induce equal and opposite charges on each surface. This potential difference is used in order to produce an electric current. The output open circuit voltage of a TENG can be predicted using the V-Q-x equation, [19], there also many other models that predict many other properties of TENGs, [20-21].

There are many factors affecting the output voltage generated during triboelectrification, one of the most important factors according to the V-Q-x equation is the charge density, which is defined as the amount of charge generated on each dielectric per unit area, once of the ways of increasing this value is by increasing the actual contact surface area between the two dielectrics, [21], that should encourage more charge exchange. However, some of the ways used to increase the actual contact surface area use complicated methods and can thus be expensive, [22-23].

In the present study, the effectiveness of increasing the actual contact surface by roughening one surface and thus increasing the output voltage using commercial emery paper is investigated.

EXPERIMENTAL

Nine 40 mm by 40 mm kapton TENG terminals were prepared. The terminal was composed of a layer of emery paper, a layer of aluminum foil above it and a layer of kapton adhered to the surface of emery paper with different grits, (36, 60, 100, 120, 180, 220, 240, 320 and 800). First, the particle size for each emery paper was measured using microscopic images, then each kapton terminal was pressed against polyamide textile (PA) adhered to aluminum foil under a specific load ranged from 2 to 12 N. The load was held for 10 seconds and then the two terminals were separated. Then the voltage at contact and separation was measured using a multimeter, then the average voltage value at contact and at separation for each setup was calculated.

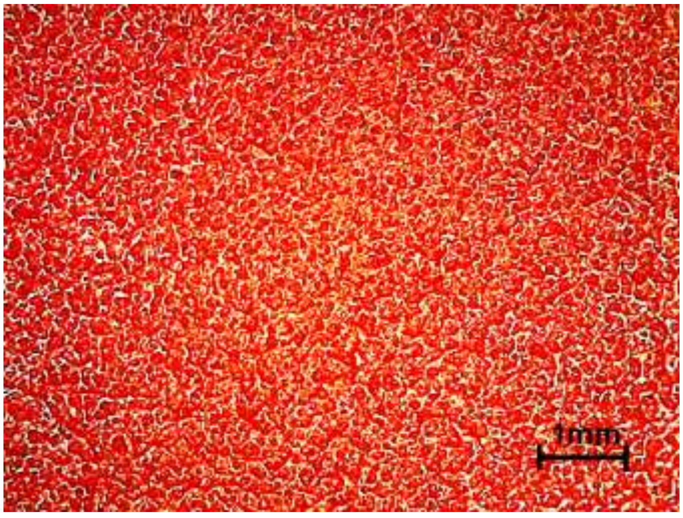

Fig. 1 Photomicrograph of 240 grit emery paper.

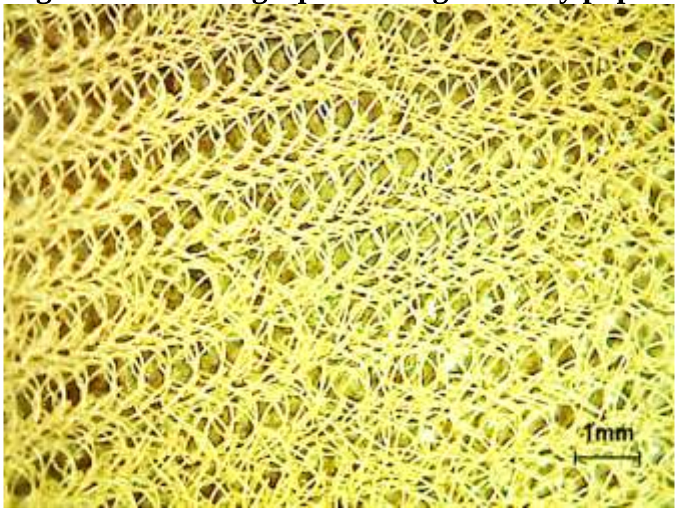

Fig. 2 Photomicrograph of PA textile.

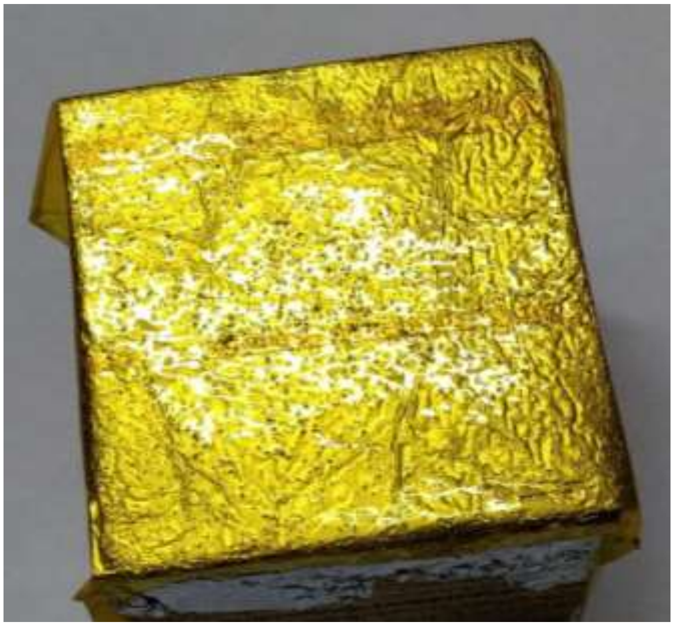

Fig. 3 Kapton terminal roughened by 100 grit emery paper.

RESULTS AND DISCUSSION

The relationship between emery paper grit and particle size is plotted in Fig. 4. to investigate the effect of particle size on the generated voltage. In Figs. 5 - 10, the relationship between emery paper particle size and output open circuit voltage of the TENG is plotted at every tested contact load.

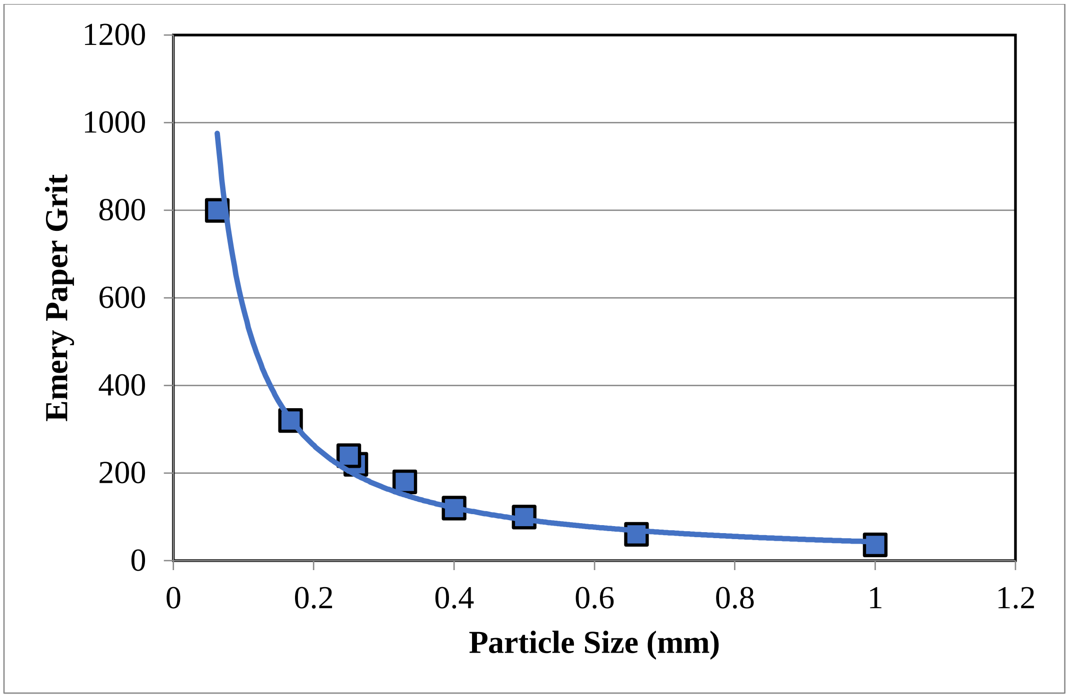

Fig. 4 Emery paper grit versus particle size.

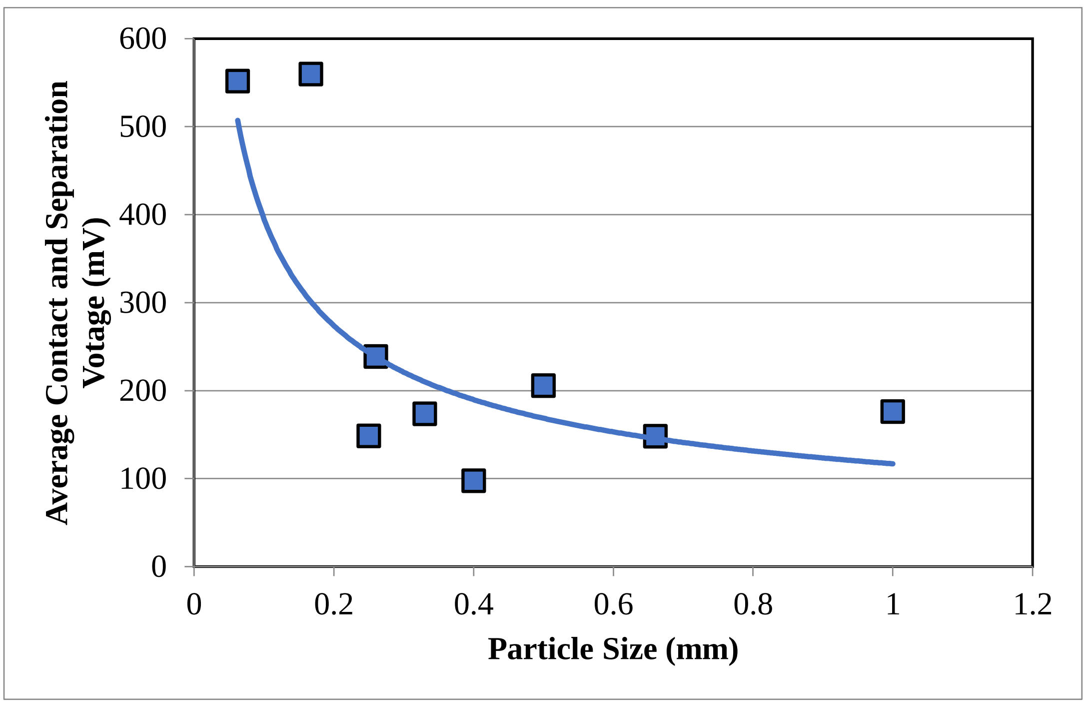

Fig. 5 Voltage versus particle size at 2 N applied load.

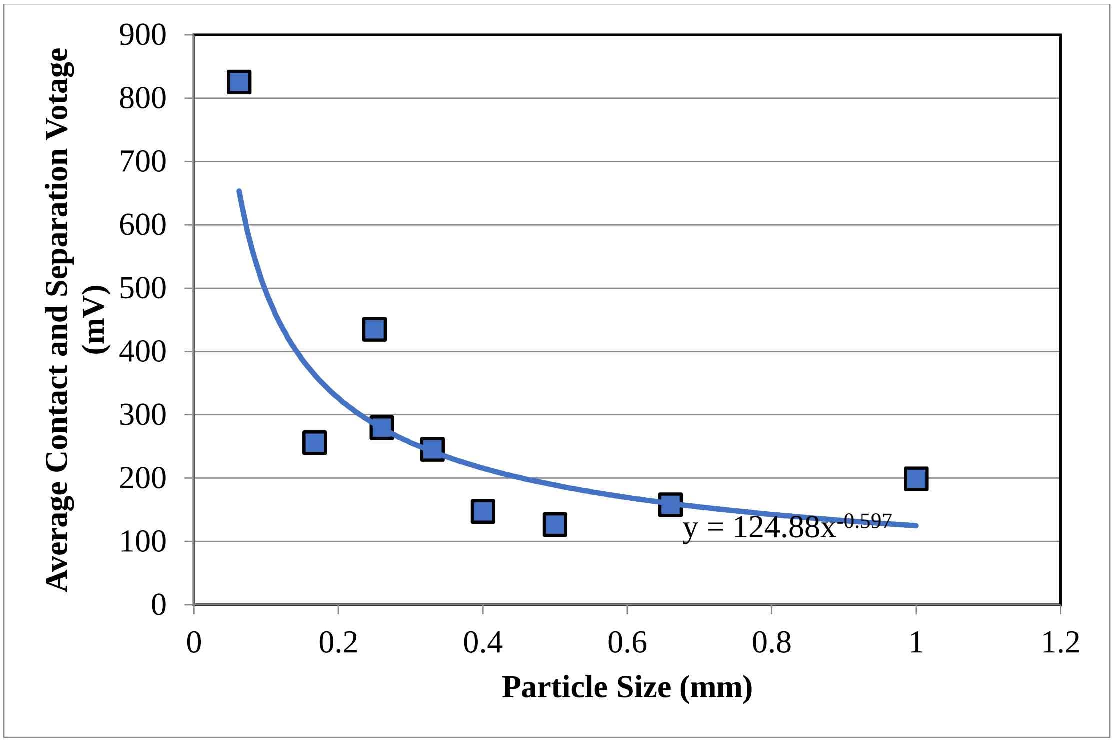

Fig. 6 Voltage versus particle size at 4 N applied load.

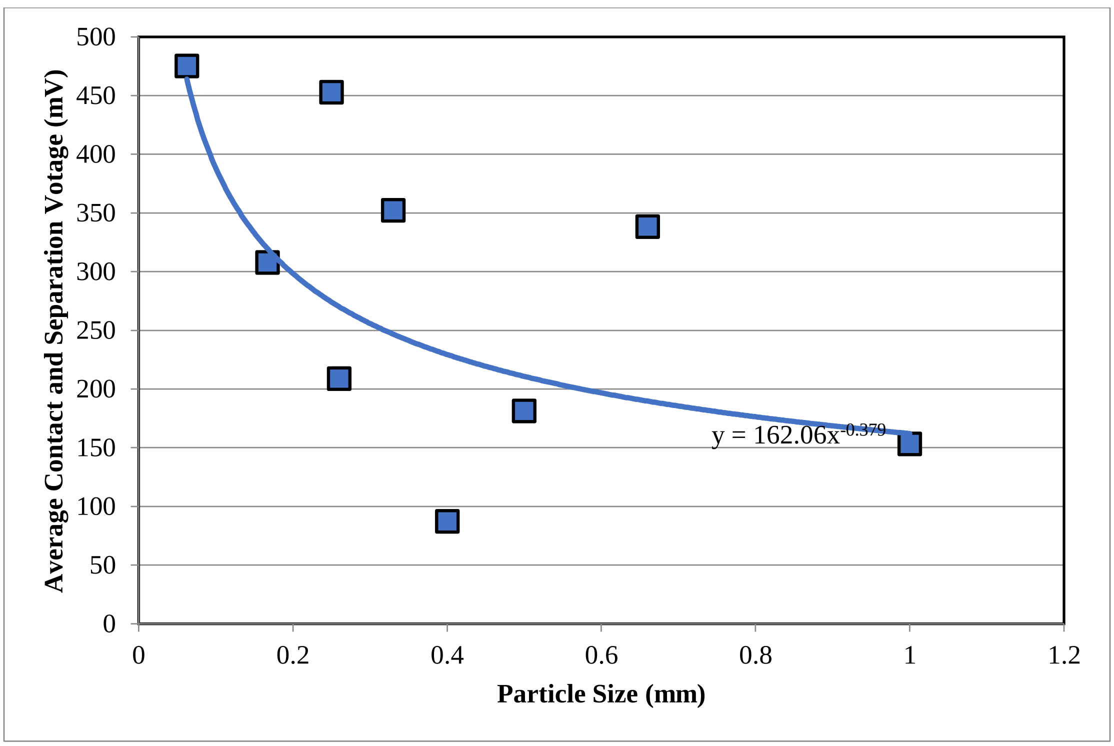

Fig.7 Voltage versus particle size at 6 N applied load.

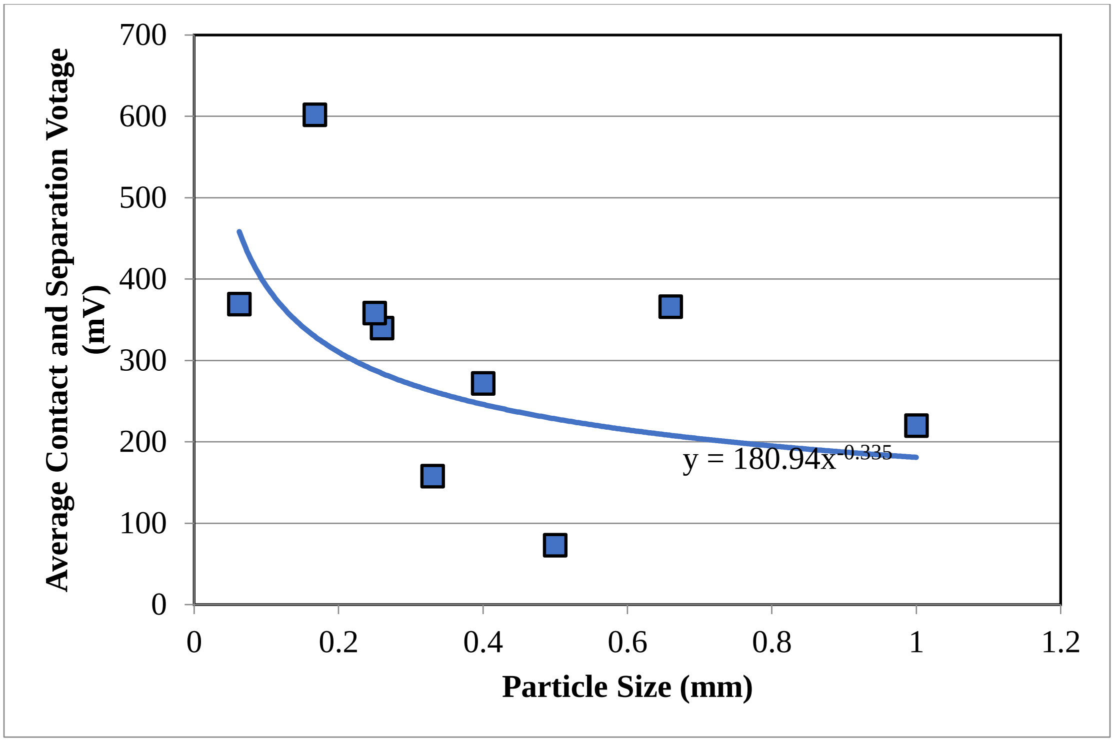

Fig. 8 Voltage versus particle size at 8 N applied load.

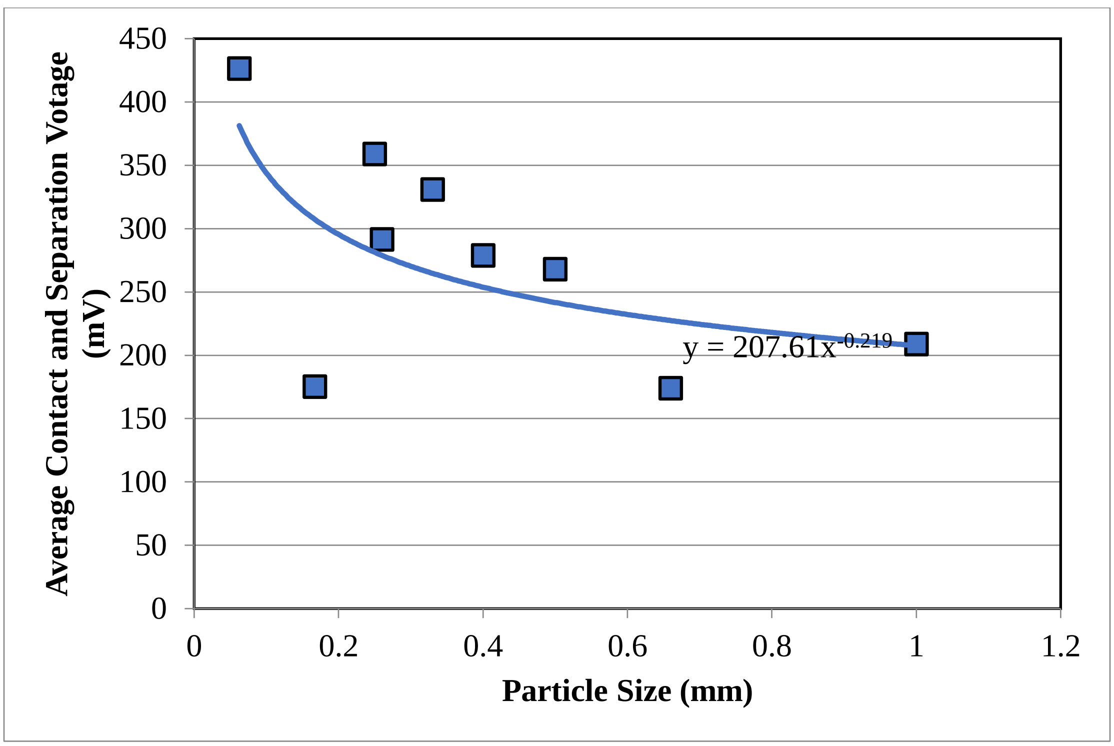

Fig. 9 Voltage versus particle size at 10 N applied load.

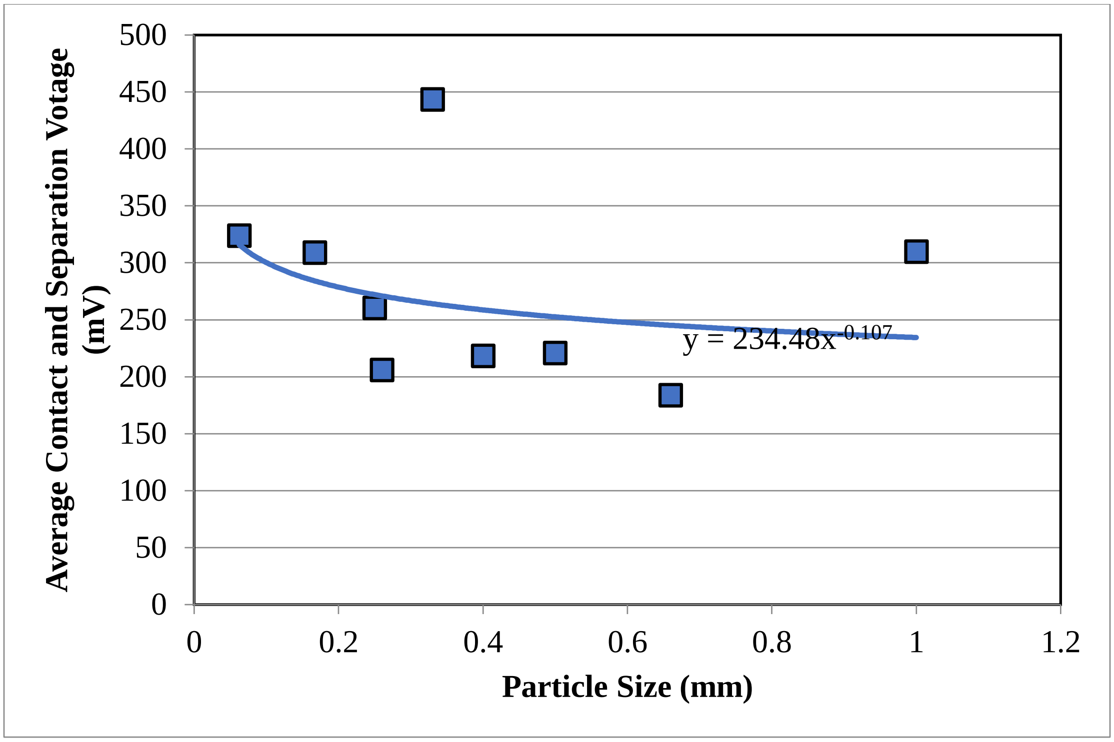

Fig. 10 Voltage versus particle size at 12 N applied load.

The same trend was observed in all the tested load values that ranged from 2 to 12 N. It is noticed that an inverse relation between voltage and particle size of the tested emery paper, where the highest voltage value was 825.5mV at particle size of 0.0625 mm and 4 N applied load. While the lowest voltage value was 73 mV at a particle size of 0.5 mm and 8 N of force. It is logic that as the particle size increases the number of particles decreases in the contact area. It is recommended to use emery paper of relatively low particles to obtain the highest voltage. It can also be noticed that as the applied load increases, the average value of the open circuit voltage tends to increase. This is to be expected as an increase in the actual contact surface area.

CONCLUSIONS

From the above experiment, the following conclusions can be drawn:

1. Decreasing the emery paper particle size caused significant increase in the output voltage.

2. Emery paper works as a cheap method of roughening the surface of a TENG, where the number of asperities increases leading to the increase of electrostatic charge generated from contact and separation.

3. The higher the value of the applied load, the higher the output voltage, where increasing the actual contact surface area of a TENG increases.

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