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PERFORMANCE OF TRIBOELECTRIC NANOGENERATOR ENHANCED BY ELECTROSTATIC INDUCTION

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ABSTRACT
The present work discusses the performance oftriboelectric nanogenerator (TENG) based on triboelectrification and magnetic induction. The voltage difference between the surfaces of polytetrafluoroethylene(PTFE) and polyamide (PA) was measured after contact-separation and sliding. PTFE was reinforced by coil of copper wires, while steel sheet fitted by permanent magnets was inserted under PA surface. Voltage difference generated on the surfaces of PTFE and PA was measured after contact-separation and sliding as function of the intensity of the magnetic field.

The present experiments revealed that voltage difference generated from contact-separation and sliding significantly increased withincreasing the intensity of magnetic field. The voltage difference is the resultant of the double charge layers generated on the surfaces of PTFE and PA, the extra electric field generated from coil and the magnetic field.The electric field offered by the coil reinforcing PTFE opposed the magnetic field supplied by the magnets and the electric field generated from friction.Increasing the wire diameter of the coil reinforcing PTFE decreased the voltage difference. Inserting steel sheet wrapped by coil under PA surface did not influence the voltage difference. This is attributed to the opposing action of the electric field offered by the coil wrapping the steel sheet to the magnetic field supplied by the permanent magnets. PTFE reinforced by steel sheet wrapped by coil of 100 turns of 0.1 mm diameter copper wire recorded significant voltage increase. Finally, it is recommended to select properly the arrangement of the construction of the TENG.

KEYWORDS
Triboelectric nanogenerator, polyamide, polytetrafluoroethylene, magnetic field, contact-separation, sliding.

INTRODUCTION

Recently, it was proved that introducing insulated copper wire coil under the PTFE surface significantly increased the voltage difference between PA and PTFE surfaces. Besides, induction of the copper coil is the reason for the voltage increase due the induced electric field, where transverse sliding showed the highest voltage, [1 - 3]. In addition to that, inserting steel sheet under PA surface significantly increased the voltage due to the increase of the magnetic field. The number of the layers of the coil influenced the highest voltage values. It was revealed that adhering steel wire in spiral form into the surface of the steel sheet showed significant voltage increase.

The warming of universe climate experienced by the high rate consumption of fossil fuels endangers the life. Renewable and clean energy are the alternative solution. TENG can be suitable to harvest mechanical energy, [4 - 6]. TENG can be achieved by contact-separation and sliding between two dissimilar materials to generate ESC, [7, 8]. The TENGs are constructed by adhering two different polarity dielectrics such as nylon, polytetrafluoroethylene (PTFE) on acrylic board.

The intensity and sign of ESCdepends on the triboelectric effect, [9 - 11], that ranks materials by the induction of positive or negative charge on the surface of thecontact material.PTFEacquires a negative charge upon contact with another material, [12], while PA is located near the top of the triboelectric series and acquires a positive charge, [13]. When PA and PTFE be in contact with each other, PTFE gainsrelatively high value of negative charge, while PA gains relatively high value of positive charge.

The TENG is madethat are on the opposite sides of the triboelectric series and then they are connected to electrodes. After contact-separation and sliding of two dielectric materials, equal and opposite charges are inducedon their surface.This voltage difference produces an electric current. The two main applications are energy harvesters, [14 - 17], and self-powered sensor, [18 - 21]. TENGs are classified into contact-separation type TENGs, [22, 23], and sliding type TENGs, [24, 25].

The effect, of induction on the generation of ESC on the surfaces of polymers slid against PA, polypropylene (PP), and PTFE, was investigated, [26 - 29]. Reinforcing PE sliding against PA by carbon fibers and metallic wires displayed relatively higher values of ESC, wheresteel wires displayed the highest ESC.

In the present work, performance of TENG based on triboelectrification and magnetic induction is discussed. The contact surface of PTFE was reinforced by coils of copper wires, while steel sheet and permanent magnets were inserted under PA surface. Voltage difference generated on the surfaces of PTFE and PA was measured after contact-separation and sliding.

EXPERIMENTAL

The presentexperiments discusses the performance of the proposed TENG. PTFE

was reinforced by insulated copper wire coil wrapped on paper frame of 20 mm height and coated by PTFE film. The counterface was prepared from PA textile adhered to wooden base of 300 mm long and 100 mm wide. The two electrodes were made from aluminium (Al) film of 0.25 mm thickness, where the first electrodewas adhered under PTFE and the second was under PA textile, Fig. 1. The effect of magnetic field on the voltage generated from the proposed TENG, was measured by inserting steel sheet of 0.25 mm thickness under PA textile. The applied load was 0.5 N. After contact-separation and sliding, the voltage difference between the two sliding surfaces was measured. The sliding distance was 200 mm for sliding. The test sliding velocitywas manually controlledto be 2 mm/s. The insulated copper wires were of 0.1, 0.2 mm and 80, 100 and 320 turns.

The test procedure consists of contact-separation and sliding. In the experiments of sliding two directions were considered. The first was the direction of the wires (longitudinal sliding), while the second was normal to the wires direction (transverse sliding), Fig. 2. In contact-separation, the load was applied for 10 seconds before measurement of the voltage was achieved. Sliding is carried by loading the PTFE on PA textile and sliding for 200 mm manually. Further experiments were carried out by inserting steel sheet fitted by coil of 0.2 mm diameter and 100 turns of insulated copper wire under PA surface, Fig. 3.

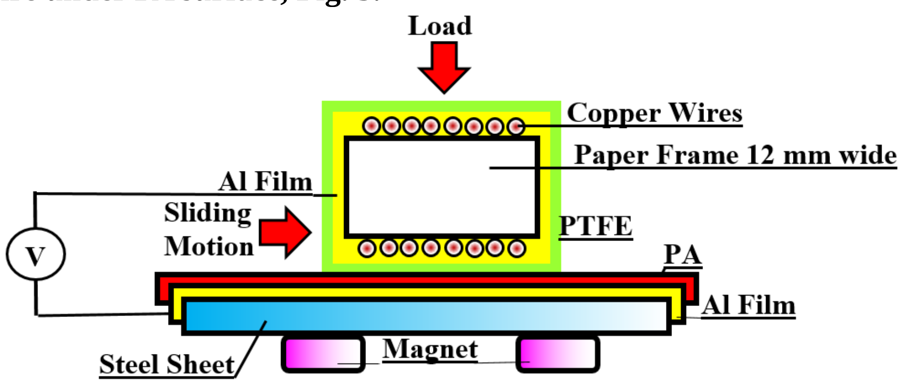

Fig. 1 Schematic sketch of the test procedure.

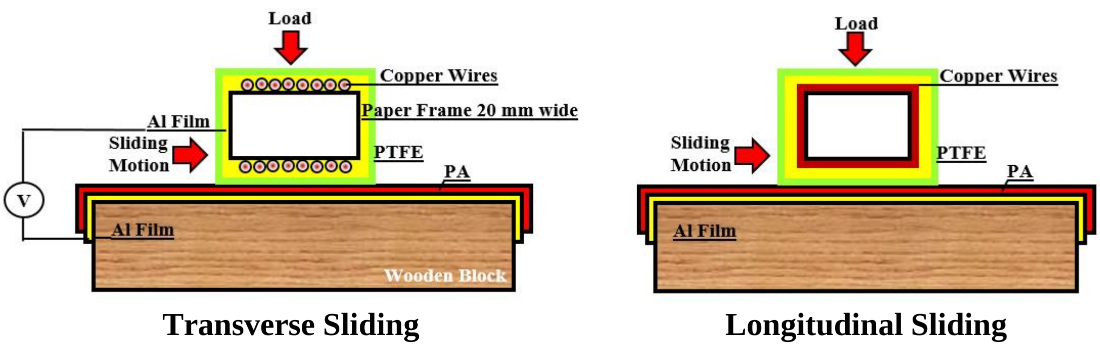

Fig. 2 Direction of sliding relative to the wire direction, [3].

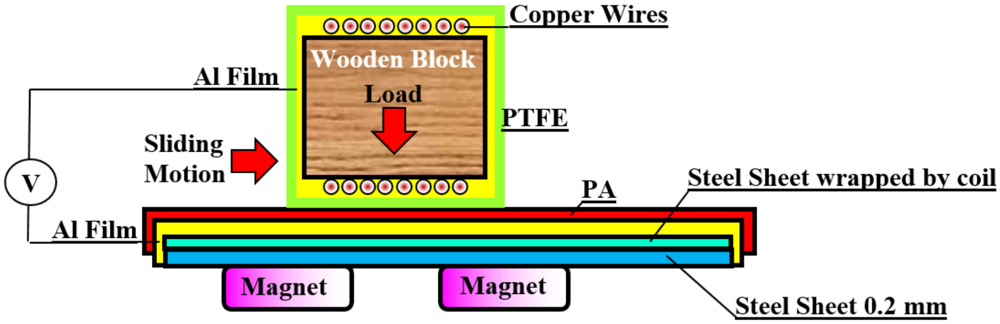

Fig. 3 Arrangement of the test specimens where sheet steel was inserted under PA.

RESULTS AND DISCUSSION

The voltage difference between PTFE reinforcedby coil of 320 turns of 0.1 mm diameter copper wires sliding on PA adhered to steel sheet, where magnets are placedunderthe steel sheet as illustrated in Fig. 1, is shown as function in intensity of the magnetic field, Fig. 4. The highest voltage values were 1250, 1295 and 1410 mV for contact-separation, longitudinal and transverse sliding respectively at 160 mG field intensity. The voltage increase confirms that the magnetic field generated from the permanent magnets is responsible for that behavior. The voltage difference is the result of the double charge layers generated on the surfaces of PTFE and PA as well as the magnetic field generated from the magnets. It is surprising that the values of voltage were relatively lower than that observed in recent work carried out without the use of the coil reinforcing PTFE, [1, 2]. It seems that the electric field offered by the coil opposed the two electric and magnetic field fields generated from the magnets and friction respectively. Distribution of the charges generated on the contact surfaces is shown in Fig. 5.The strength of the electric field affecting the contact surface influences the intensity of generated ESC. The generation ofboth electric and magnetic fields creates an electromotive force (voltage). The voltage increase depends mainly on the electric field. On the other side, the magnetic field caused by the presence of the magnets strengthens the electric field generated from the double ESC layer. The resultant ESC increasesin the presence of the magnets.

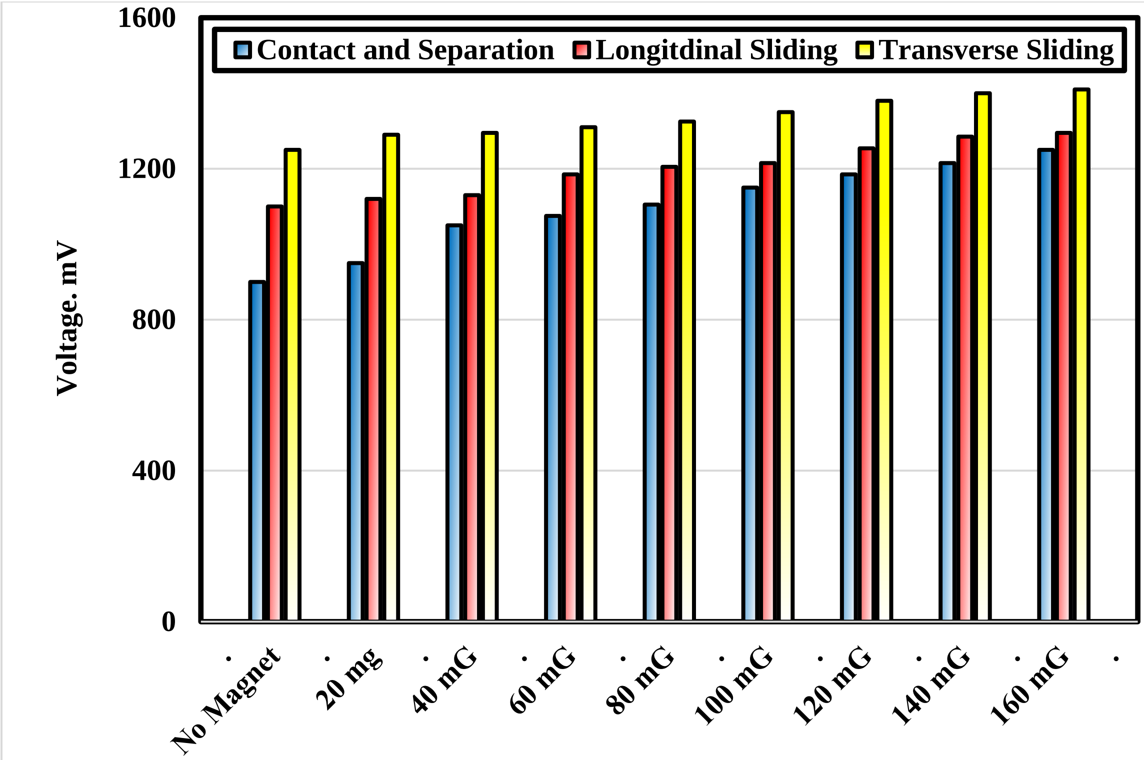

Fig. 4 The voltage difference between PTFE, reinforced by coil of 320 turns of 0.1 mm diameter,and PA adhered to steel sheet, where magnets are placedunder PA surface.

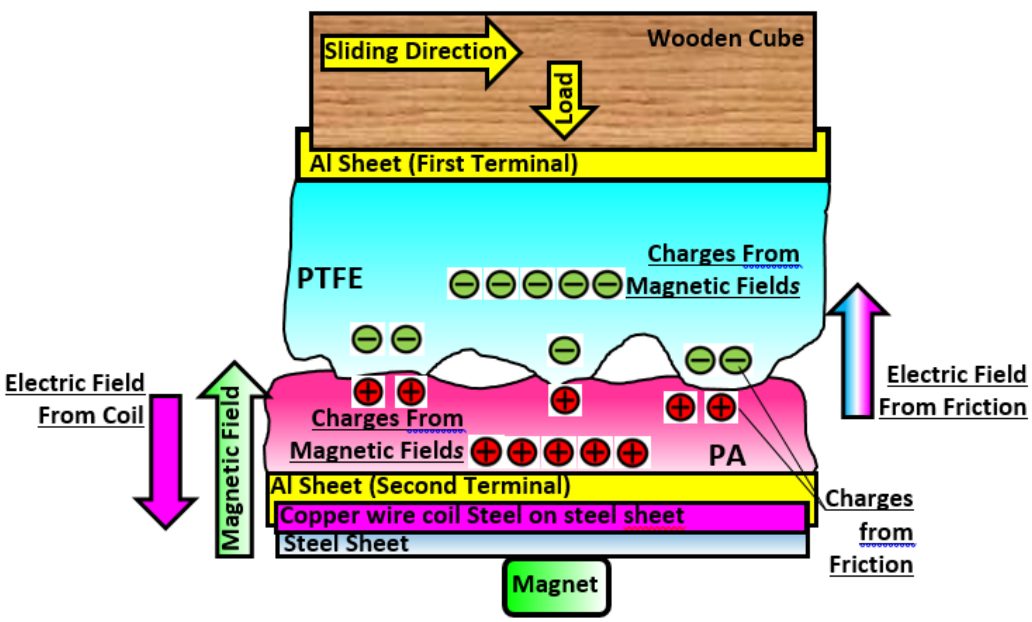

Fig. 5 Illustration of the distribution of the ESC generated on the contact surfaces.

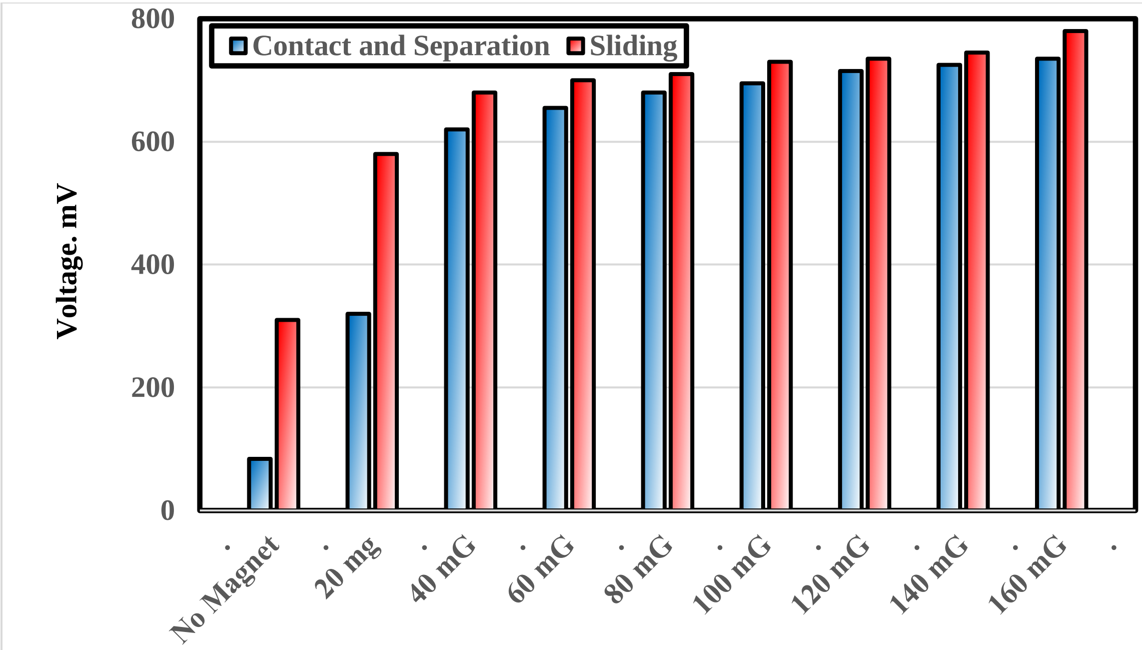

Fig. 6 The voltage difference between PTFE reinforced by coil of 100 turns of 0.2 mm diameter copper wire sliding on PA adhered to steel sheet supplied by permanent magnets.

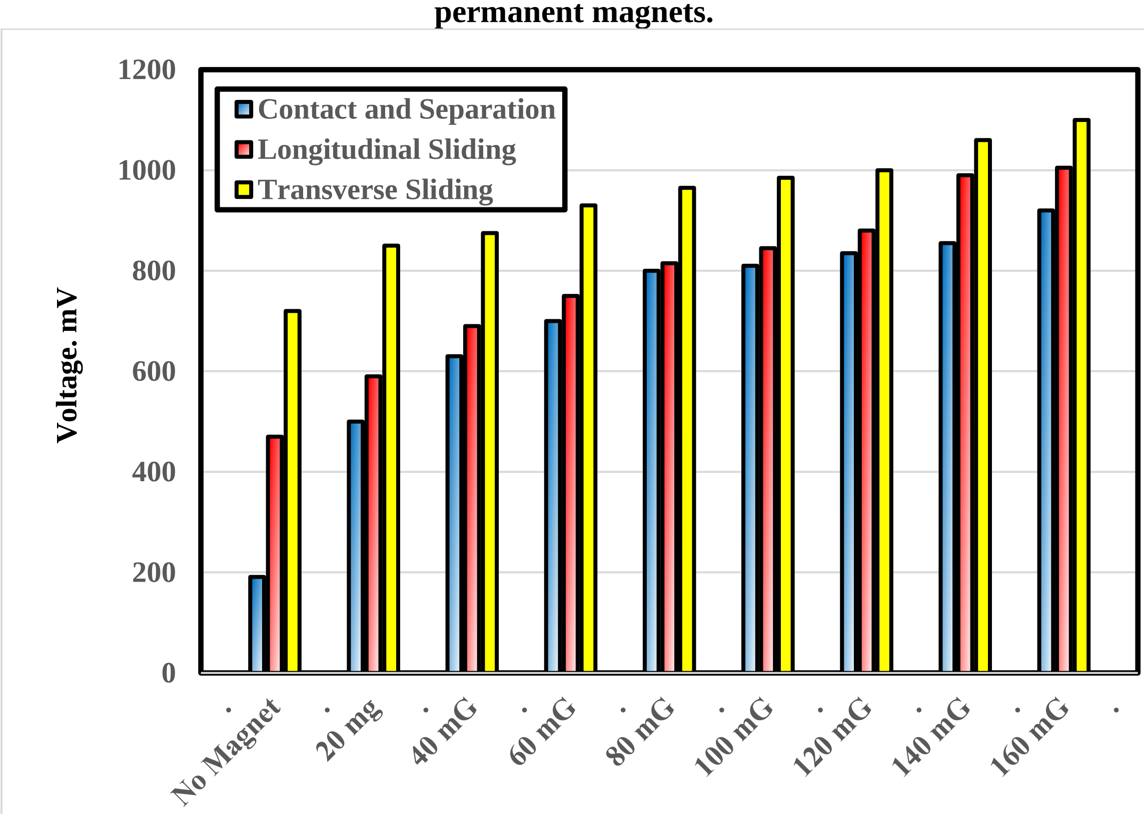

Fig. 7 The voltage difference between PTFE, reinforced by coil of 320 turns of 0.1 mm diameter, and PA adhered to steel sheet, where coil wrapping steel sheet and magnets are placedunder PA surface.

When PTFE was reinforced by coil of 100 turns of 0.2 mm diameter copper wire and sliding on PA, voltage difference decreased to 735and 780 forcontact-separation and sliding respectively, Fig. 6. It seems that increasing the wire diameter increased the electric field induced by the coil. That electric field opposed both themagnetic field and the electric field generated from the double ESC layer. According to that, the resultant field decreased and consequently the voltage difference decreased.

The voltage difference between PTFE, reinforced by coil of 320 turns of 0.1 mm diameter, and PA adhered to steel sheet, where coil of 0.1 mm diameter copper wire of 100 turns wrapping steel sheet and magnets are placed under PA surface is shown in Fig. 7. It was observed that inserting the coil under PA surface did not enhance the voltage difference, where the voltage values were lower than that recorded in the condition illustrated in Fig. 4. It seems that the coil inserted under PA generated an electric field that opposed the resultant of the magnetic field and the electric field generated from the double ESC layer.

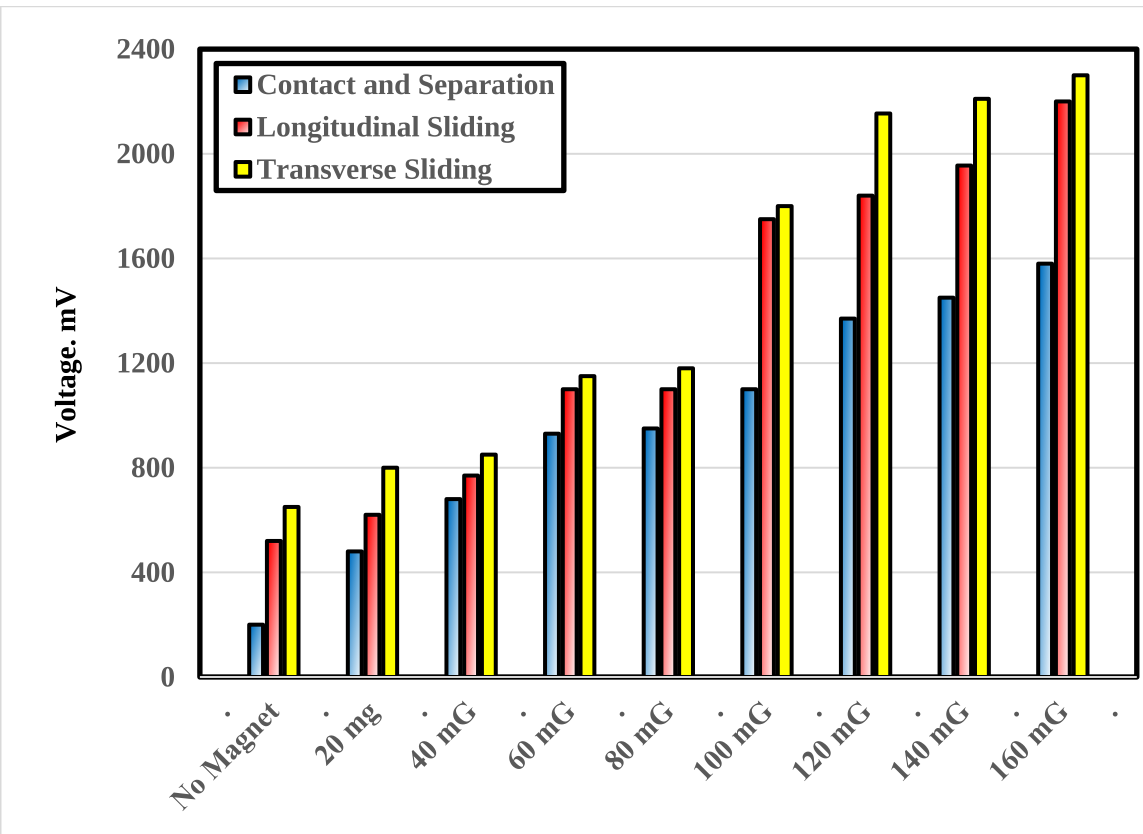

Fig. 8 The voltage difference between PTFE reinforced with coil of 100 turns of 0.1 mm, diameter copper wire sliding on PA adhered to steel sheet supplied by magnets.

Figure 8 describes the relationship between voltage difference between PTFE reinforced by steel sheet wrapped by coil of 100 turns of 0.1 mm diameter copper wire sliding on PA adhered to steel sheet suppliedby permanent magnets. Remarkable voltage increase was observed, where the highest value was 2300 mV

for transverse sliding at 160 mG field intensity. As expected, the voltage increased when the intensity of the magnetic field increased. The experimental observations in the present work confirms the need to select properly the arrangement of the construction of the TENG.

CONCLUSIONS

1. Voltage difference generated from contact-separation and sliding significantly increased withincreasing the intensity of magnetic field.
2. The voltage difference is the resultant of the double charge layers generated on the surfaces of PTFE and PA, the extra electric field generated from coil as well as the magnetic field supplied by the permanent magnets.
3. The electric field offered by the coils reinforcing PTFE opposed the electric fields generated from friction and the magnetic field supplied by the magnets.
4. Increasing the wire diameter of the coil reinforcing PTFE decreased the voltage difference.
5. Inserting steel sheet wrapped by coil under PA surface did not influence the voltage difference. This is attributed to the opposing action of the electric field offered by the coil wrapping the steel sheet.
6. PTFE reinforced by steel sheet wrapped by coil of 100 turns of 0.1 mm diameter copper wire recorded significant voltage increase.
7. It is recommended to select properly the arrangement of the construction of the TENG.

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