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ELECTRONIC SKIN BASED ON TRIBOELECTRIFICATION AND ELECTROSTATIC INDUCTION

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ABSTRACT

The present work proposes an electronic skin (e-skin) on the basis of the triboelectric effect and electrostatic induction with proper artificial tactile property. A lightweight e-skin responds to contact-separation and sliding with the object is illustrated. The e-skin consisted of carbon fibers (CF) coil wrapped on aluminium film of 0.1 mm thick as the electrode in PMMA core, while outer friction surface that generates the electrostatic charge (ESC) is composed of 0.1 mm thick Kapton film coating the substrate. Polytetrafluoroethylene (PTFE) replaced Kapton to evaluate the performance of both Kapton and PTFE. The surface of the object was PA textile. The e-skin in form of substrate adhered to the finger has the ability to self-generate feedback electric signals. The proposed design can generate voltage from contact-separation and sliding.

It was found that voltage difference between Kapton/PA and PTFE/PA after contact-separation and sliding increased as the applied load increased. Both Kapton and PTFE fitted by CF showed relatively higher voltage because CF increased the voltage due to the electric induction. In addition to that, transverse sliding displayed higher voltage than that recorded for sliding in the direction of the CF. PTFE/PA displayed higher values of voltage than Kapton/PA. It can be recommended that the values of the voltage difference can be used as feedback signal to control the input voltage of the control motor that moves the finger fitted by e-skin. Besides, it is aimed in future work to propose a closed-loop control system of secure and safe grasping.

KEYWORSD

Electronic skin, triboelectrification, electrostatic induction, Kapton, carbon fibers.

INTRODUCTION

The major factor in characterizing e-skin is to generate feedback electric signal according to contact-separation and sliding on the object surface, [1]. Several attempts have been carried out to develop e-skin by resistive and capacitive sensors, [2 - 5]. Triboelectric nanogenerators (TENGs) based on triboelectrification and electrostatic induction were used to design,[6 - 13]. Besides, several types of e-skin have been successfully introduced to detect finger touch, [14, 15]. Recently, a gripper design was proposed to guarantee safe grasp of objects, where the sliding of the object on the gripper surface was controlled to prevent the excessive increase of the gripping force. The feedback of the system depends on the triboelectrification and generates double layers of ESC at the two contact surfaces, [16].

The grip object manipulation depends on the grip force to guarantee secure grip, [17]. In absence of the control system of grip force, the risk of dropping or crushing the object is raising, [18 - 21]. The grip force was controlled by controller that depends on the load force feedback, [22 - 26], where load cell was used to measure the grip and the tangential force applied on the two fingers of robotic gripper considering static friction. To achieve precise grip force control system, static coefficient of friction, grip force and weight of the object should be considered.

In the present work, an electronic skin (e-skin) on the basis of the triboelectric effect and electrostatic induction is proposed. The e-skin in form of substrate adhered to the finger is able to generate electric feedback signals from contact-separation and sliding.

EXPERIMENTAL

Test specimens were prepared from polymethyl methacrylate (PMMA) sheet of 1.0 mm thickness of 25 × 15 mm^2, covered by aluminium film (Al) of 0.1 mm thickness to work as the first terminal. Kapton film of 0.04 mm thickness was adhered on the Al film representing the first dielectric surface. Under Kapton, carbon fibers coil was placed to provide the system with electric induction and increase the conductivity of Al film. The content of CF was 20 wt. % relative to Kapton film. PTFE replaced Kapton to evaluate the performance of both Kapton and PTFE. The counterface was PA in form of textile adhered on Al film (second terminal) that covered PMMA sheet of 2.0 mm thickness representing the second dielectric surface.

The load was applied by weights (0, 2, 4, 6, 8 and 10 N). The sliding distance was 200 mm. The details of the test specimens and the test rig are shown in Figs. 1, 2. Experiments were repeated five times to measure the voltage difference. The test was contact-separation, where the load was applied for 5 seconds followed by the measurement of the voltage, and sliding in two direction, the first in direction of the CF (longitudinal sliding) and the second normal to the CF direction (transverse sliding).

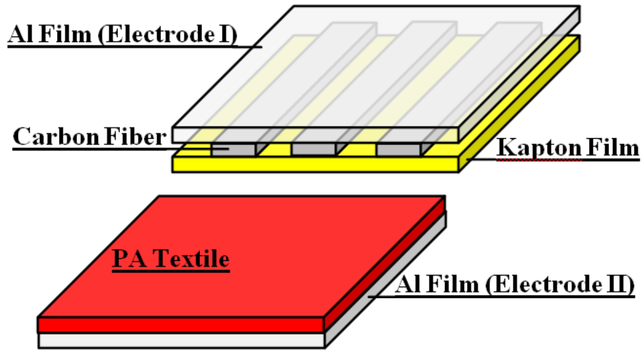
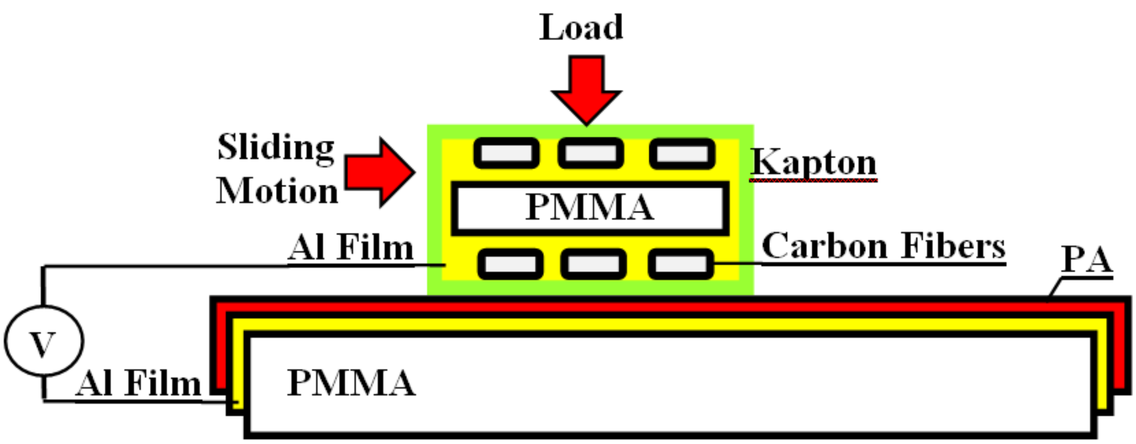
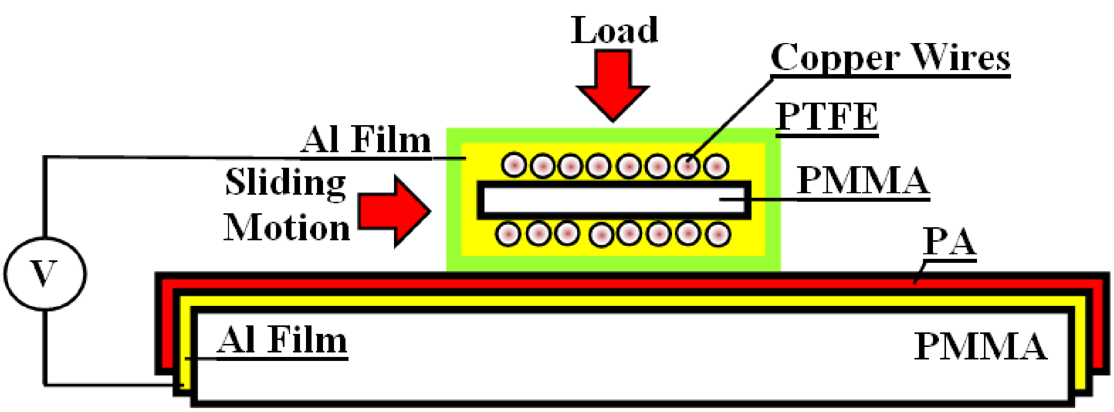


Fig. 1 Details of test specimens.



a. Kapton/PA.



b. PTFE/PA.

Fig. 2 Arrangement of the test rig.

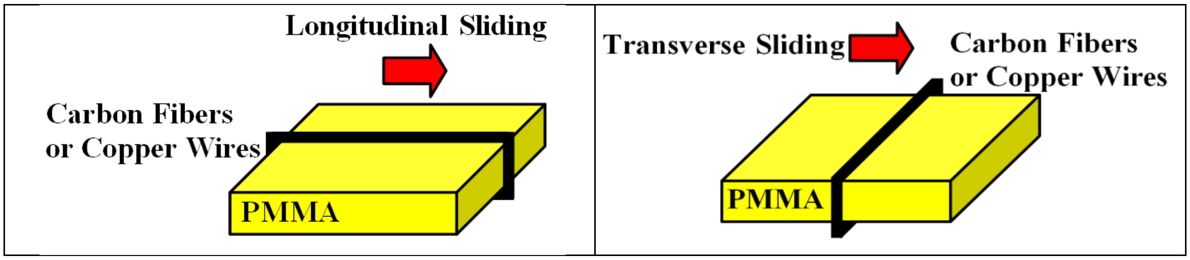


Fig. 3 Direction of Sliding.

RESULTS AND DISCUSSION

Voltage difference measured in mV between Kapton and PA after contact-separation is shown in Fig. 4. Voltage increased as the applied load increased due to the increase of the contact area. The highest value of ESC was observed at 10.3 N load. Experiment carried out using Kapton surface wrapped by CF coil showed higher voltage than Kapton without CF, where voltage difference reached 67 mV, while that recorded for Kapton free of CF was 41 mV. It seems that presence of CF increased the voltage due to the electric induction.

The voltage difference is generated due to the triboelectrification is defined as the gain or loss of electrons due to friction, where electrons are transferred from one of the contact surface to the other after contact-separation and sliding of insulating materials. Voltage difference measured between Kapton and PA from the sliding, Fig. 5, showed significant increase compared to contact-separation. CF generated the highest voltage values up to 101 mV at 10.3 N load. As the diameter of the wires increased, voltage decreased.

It is clearly shown that CF were able to induce relatively higher electric field. When an electric conductor (CF) is moved through an electric field, or an electric field moves through CF, an electric current will be induced and flow into CF. The induced electric field increases the voltage significantly in the presence of CF. Figure 6 illustrates the effect of sliding direction on the voltage, where sliding in the direction transverse to the direction of CF displayed higher voltage than that recorded in the direction of the fibers. The values of voltage were 115 and 101 mV for Kapton blended by CF and Kapton free of CF respectively at 10. 3 N load.

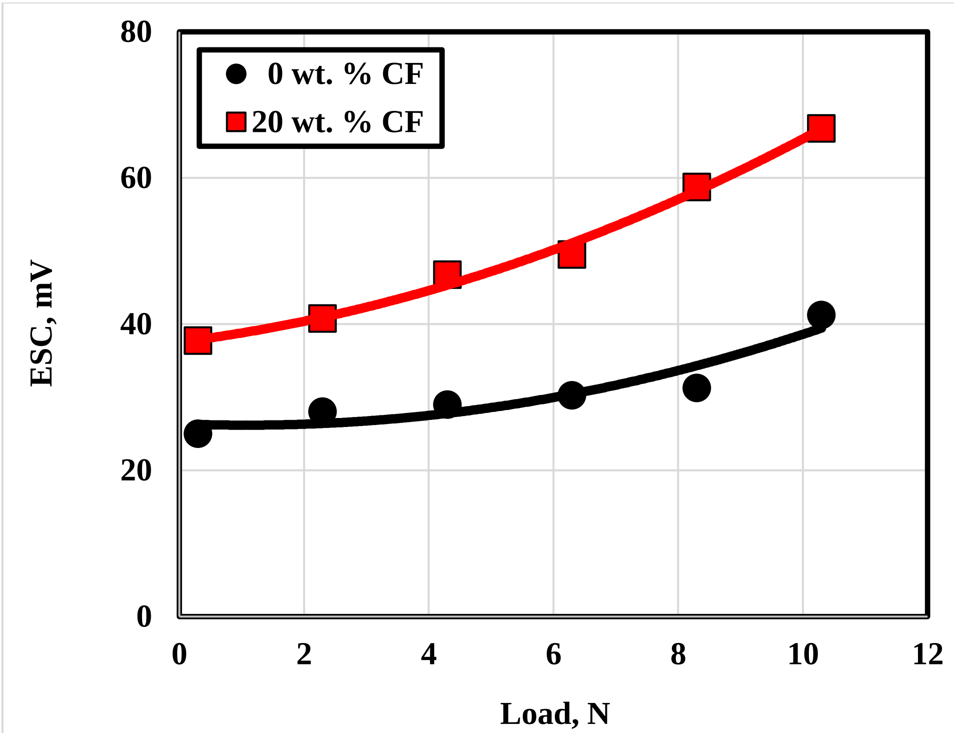


Fig. 4 Voltage difference measured between Kapton and PA from the contact-separation.

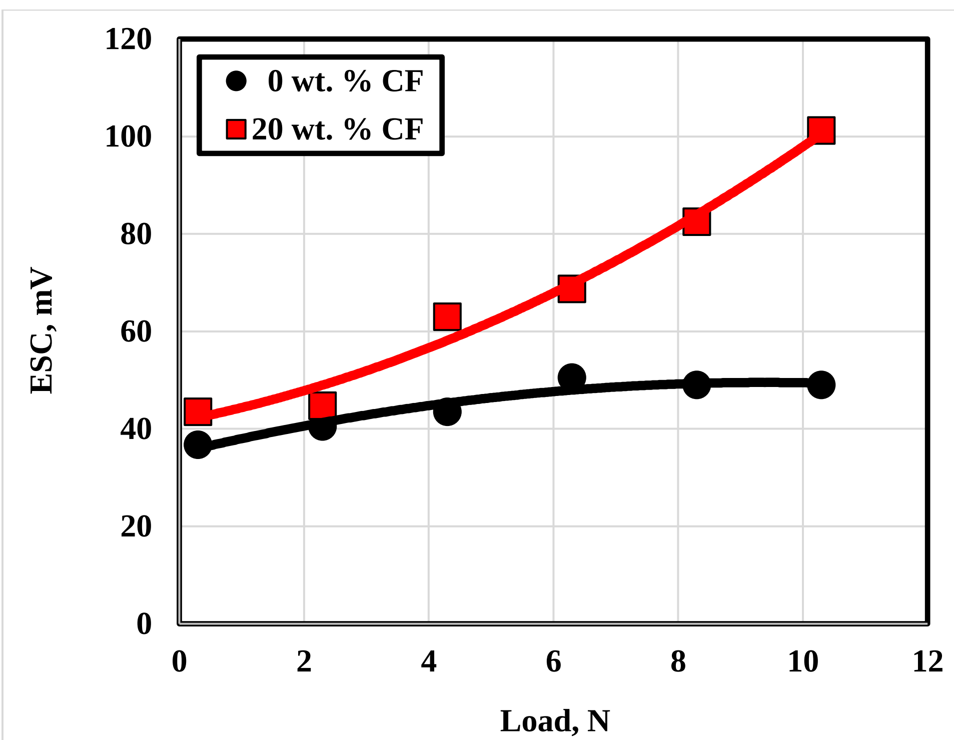


Fig. 5 Voltage difference measured between Kapton and PA from the sliding.

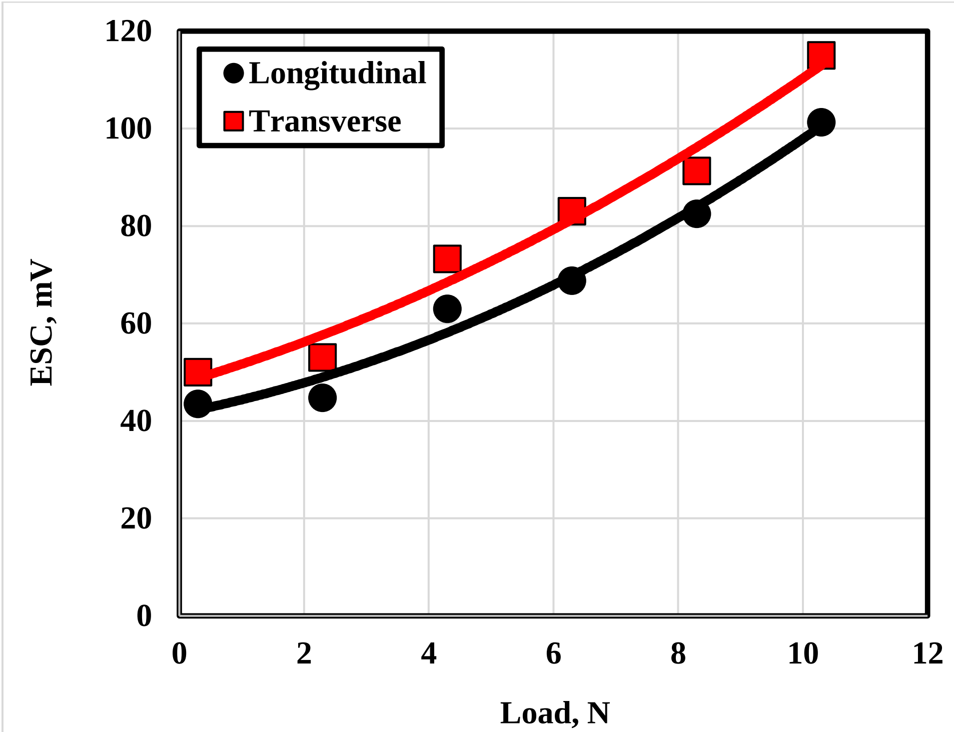


Fig. 6 Effect of sliding direction on voltage difference measured between Kapton and PA.

The results of replacing Kapton by PTFE are shown in Figs. 7 – 9. The same trend of the Kapton/PA is observed for PTFE/PA. The exception is that the voltage values are higher for PTFE/PA. This behavior is attributed to the rank of PTFE and Kapton in the triboelectric series, where PTFE is lying in the bottom of the series representing the most aggressive material of negative ESC. The influence of CF on the voltage difference between the two contact surfaces was significant. The voltage difference from contact-separation of PTFE and PA as function in the applied load is shown in Fig. 7. CF increased the voltage compared to that observed from Kapton free of CF. It was found that sliding displayed relatively higher voltage than contact-separation, Fig. 8. Transverse sliding displayed the highest voltage values, Fig. 9. The highest values of voltage were 183 and 156 mV for transverse and longitudinal sliding respectively. It is observed that the voltage in the presence of CF showed higher values than that measured for surfaces free of wires. This behvior may be due to that the double layer of ESC generated on the contact surfaces of PTFE and PA induced an extra electric field on the sliding surfaces leading to the voltage increase.

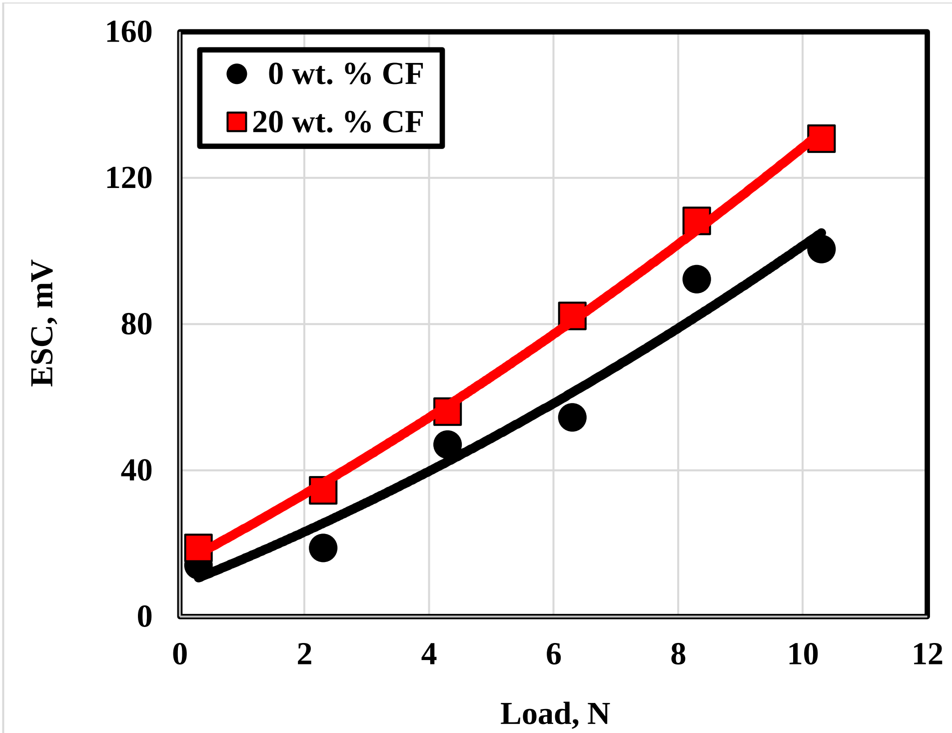


Fig. 7 Voltage difference measured between PTFE and PA from the contact-separation.

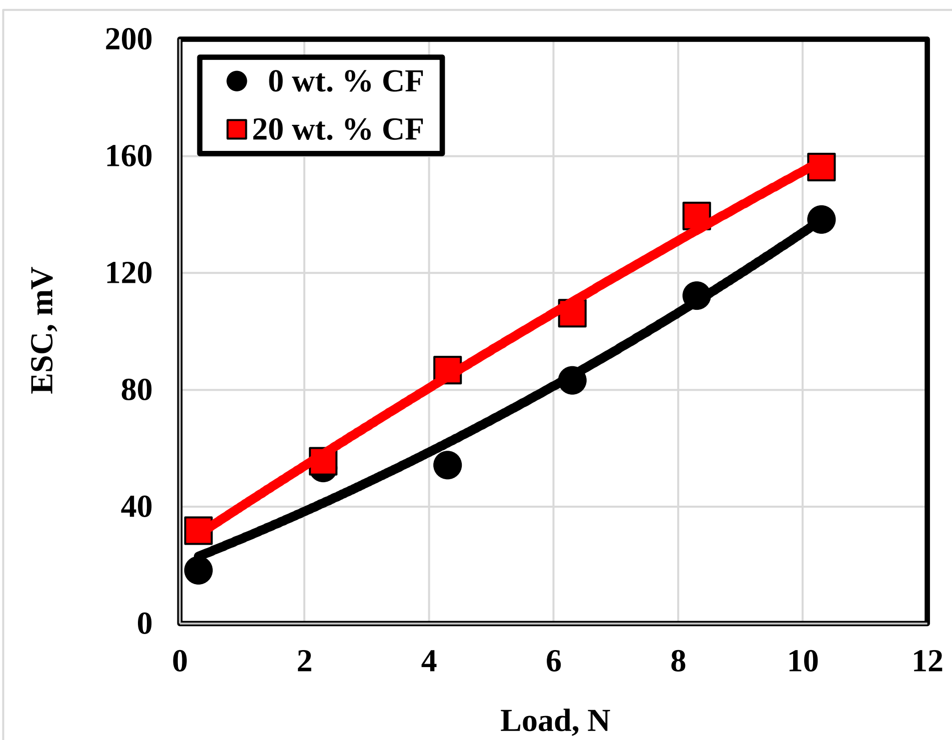


Fig. 8 Voltage difference measured between PTFE and PA from the sliding.

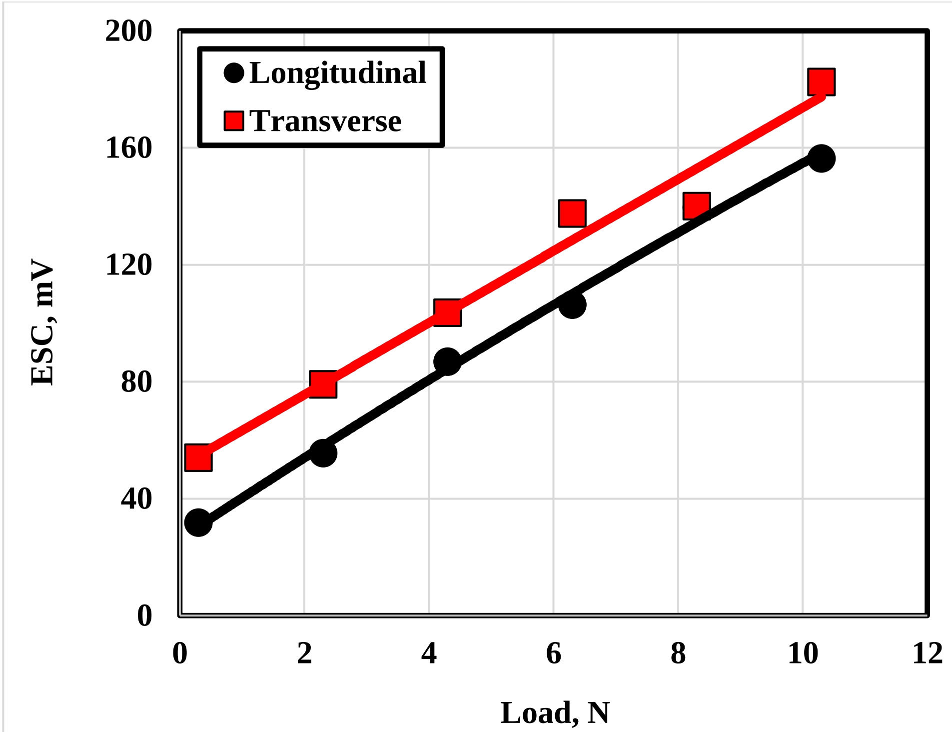


Fig. 9 Effect of sliding direction on voltage difference measured between PTFE and PA.

It is aimed to control the contact-separation and sliding of the object on the surface of the e-skin. The feedback action of the e-skin depends on the triboelectrification, where the electrification will be produced at the contact surfaces and generates positive and negative ESC. After contact-separation and sliding of the two contact surfaces, that represents the condition of slip or sliding of the object, the e-skin will gain ESC that works as feedback signal to increase the gripping force by increasing the input voltage of the control system, where the magnitude of adhesion force between the e-skin and object increases so that the object tightly can be grasped. In the present work, triboelectrification is the source of the feedback signal. The feedback signal controls the input voltage of the driving motor that moves the finger fitted by e-skin. In the future work, closed-loop control system is suggested to achieve reliable grasping.

CONCLUSIONS

1. Voltage difference between Kapton and PA after contact-separation and sliding increased as the applied load increased due to the increase of the contact area.
2. Kapton and PTFE surfaces wrapped by CF showed higher voltage than that without CF, where presence of CF increased the voltage due to their induction.
3. Voltage difference measured from the sliding showed relatively higher increase compared to contact-separation.
4. CF induced relatively higher electric field that significantly increased the voltage.
5. Transverse sliding displayed higher voltage than that recorded for sliding in the direction of the fibers.

6. The same trend of the Kapton/PA is observed for PTFE/PA with relatively higher values of voltage.
7. The values of the voltage difference can be used as feedback signal that controls the input voltage of the driving system that moves the finger fitted by e-skin.
8. It is aimed in the future work to design a closed-loop control system to achieve secure and reliable grasping.

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