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# ELECTROSTATIC CHARGE GENERATED FROM SLIDING OF HIGH DENSITY POLYETHYLENE AGAINST AIR BUBBLE SHEET OF LOW DENSITY POLYETHYLENE

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## ABSTRACT
**The present work investigates the electrostatic charge (ESC) generated from contact and separation as well as sliding of high density polyethylene (HDPE) on the air bubble sheets. They are made of low-density polyethylene (LDPE) of air-bubbles. They have protruding air bubbles that are regularly spaced. The test specimens were prepared from HDPE hollow cylinder of 50 mm diameter, 60 mm height and 1.0 mm thickness. The air bubble sheet was single layer and double layers separated by aluminium film (Al), CF textiles, copper textiles and stainless steel sheet. The HDPE was wrapped by copper and iron wires of 0.15 mm diameter of 50 turns (2500 mm).**

**It was found that, ESC generated on HDPE sliding against LDPE showed increasing trend with increasing the sliding distance. HDPE wrapped by steel wires recorded higher values followed by copper wires, while HDPE free of wires the lowest ESC. It is believed that the intensity of the E-field increased in the presence of iron wires due to the generation of magnetic field whose intensity was higher than that supposed for copper wires. ESC can be reduced by reinforcing LDPE layers by conducting sheet such as CF, Al film and copper textiles. ESC generated on the surface of HDPE after sliding against LDPE reinforced by aluminium film was higher than that observed for CF reinforced LDPE. Finally, after HDPE free of wires, the highest value of ESC was generated on the LDPE reinforced by steel sheet followed by copper textiles.**

## KEYWORDS
**Electrostatic charge, carbon fibres, copper, iron, air bubble sheet, high and low density polyethylene.**

## INTRODUCTION
**Air bubble sheets are flexible packaging material made of low-density polyethylene of air-bubble diameter varies from 6 - 26 mm that protect fragile products and prevent damages caused by impacts and shocks, [1]. They are used to wrap technical items. They have protruding air bubbles that are regularly spaced. There is increasing demand to investigate the electrostatic charge (ESC) generated from sliding of polymers on the air bubble sheets. ESC generated from sliding of PE on polytetrafluoroethylene (PTFE) is**

**investigated, [2]. The effect of reinforcing polyethylene by copper and iron wires is tested. Tests have been carried out at dry sliding. It was found that as the gap thickness of the hollow box coated by PTFE increased ESC decreased. ESC generated during contact and separation as well as sliding controls friction coefficient. The strength of the electric field crossing the sliding surface is proportional to how much ESC is generated. That behviour can be interpretted on the basis that the double layer of ESC generated on the sliding surfaces of PE and PTFE would generate an E-field inside the gap. Presence of copper wires inside PE matrix would generate extra ESC on the sliding surfaces due to the generation of electric field which affected the sliding surfaces by extra electric charge. Reinforcing PE by iron wires generated higher ESC than the other tested composites. It seems that the intensity of the E-field increased in the presence of iron wires.**

**The effect of reinforcing PE by copper wires on the generation of ESC when slid against PTFE, polypropylene (PP), and polyamide (PA) has been investigated, [3]. It was found that, reinforcing PE by carbon fibres (CF) and metallic wires sliding against PA recorded relatively higher values of ESC than that observed for unreinforced PE. Steel wires showed the highest values followed by carbon fibres while the lowest values were displayed by copper wires. That behviour can be interpretted on the basis that the double layer of the electrostatic charge (ESC) generated on the sliding surfaces of PE and PA would generate an E-field inside the matrix of PE. Presence of carbon fibres or metallic wires inside PE matrix would generate extra electrostatic charge on the sliding surfaces. Besides, ESC generated from PE reinforced by copper wires sliding against PA increased with increasing wire diameter. It seems that the intensity of the E-field increased with increasing the copper diameter due to the increase of electric current flowing through the wire leading to the increase of the E-field.**

**The effect of reinforcing epoxy by copper wires of different diameters on the generation of the electric static charge and friction coefficient when rubber sole slides against epoxy floor was investigated, [4 - 7]. Tests have been carried out at dry sliding. The effect of number of wires, location and wires diameter inside the matrix of the epoxy was studied. It has been found that at the electrostatic charge measured in volts significantly increased with increasing the number of wires. As the sliding distance increased voltage increased. Voltage decreased with increasing the distance of wire location from the sliding surface. When the wires were closer to the surface, the generated voltage increased. Besides, the increase in the wire diameter caused significant voltage increase. At water wetted sliding, voltage decreased due to the good water conductivity. As the sliding distance increased, the generated voltage decreased.**

**The addition of copper and brass particles into epoxy matrix displayed higher values of voltage than that observed for epoxy filled by iron particles, [8]. Voltage was influenced by the load, where it increased with load increasing. It was observed that the maximum level of the voltage generated from the friction of materials is dependent on their position in the triboelectric series relative to the counterface, [9]. The triboelectric series can be used to determine the charge polarity of the materials. This series can be used to evaluate the relative charging capacity of many polymeric materials.**

**It is necessary to study the electrification of engineering materials. The increased uses of polymeric materials raised the importance of studying that effect. It is well known that when two different materials contact each other, they may get charged. Electrostatic**

**charges (ESC) generated from friction of engineering materials have a negative effect in the health of the peoples. In football, goalkeeper needs gloves to keep his hand safe and enhance his ability to catch the ball. Quantitative measurements of the ESC generated from the sliding of the ball against the glove surface were carried out, [10]. The experiments showed that ESC generated on the glove surface could be controlled by proper selection of the materials of appropriate surface qualities for practical use. ESC values generated from the sliding of the ball on the gloves of the goalkeeper can be doubled and accumulated so that they affect his physical condition during the match.**

**ESC generated from sliding of PE on PTFE was investigated, [11]. The effect of reinforcing polyethylene by copper and iron wires was tested. Tests have been carried out at dry sliding. It was found that as the gap thickness of the hollow box coated by PTFE increased ESC decreased. ESC generated during contact and separation as well as sliding controls friction coefficient. The strength of the electric field crossing the sliding surface is proportional to how much ESC is generated. That behviour can be interpretted on the basis that the double layer of ESC generated on the sliding surfaces of PE and PTFE would generate an E-field inside the gap. Presence of copper wires inside PE matrix would generate extra ESC on the sliding surfaces due to the generation of electric field which affected the sliding surfaces by extra electric charge. Reinforcing PE by iron wires generated higher ESC than copper wires. It seems that the intensity of the E-field increased in the presence of iron wires.**

**The aim of the present study is to investigate electrostatic charge generated from sliding of high density polyethylene against air bubble sheet of low density polyethylene.**

## EXPERIMENTAL

**The present work discusses ESC generated from contact and separation as well as sliding of high density polyethylene against air bubble sheet of low density polyethylene. The test specimens were prepared from HDPE hollow cylinder of 50 mm diameter, 60 mm height and 1.0 mm thickness. The cylinder was pressed and slid against air bubble sheet of low density polyethylene. The air bubble sheet was single layer and double layers, Figs. 1 and 2, separated by aluminium film (Al), CF textiles, copper textiles and stainless steel sheet. The HDPE was wrapped by copper and iron wires of 0.15 mm diameter of 50 turns (2500 mm).**

**The applied force was 10 N for ESC measurements. After sliding, the ESC generated on the two sliding surfaces was measured. The sliding distance was 0 (contact and separation), 50, 100, 150, 200 and 250 mm. The test speed was nearly controlled to be 2 mm/s. All measurements were performed at 28 ± 2º C and 50 ± 10 % humidity. The electric static fields (voltage) measuring device (Ultra Stable Surface DC Voltmeter) was used to measure the electrostatic charge (electrostatic field) for test specimens.**

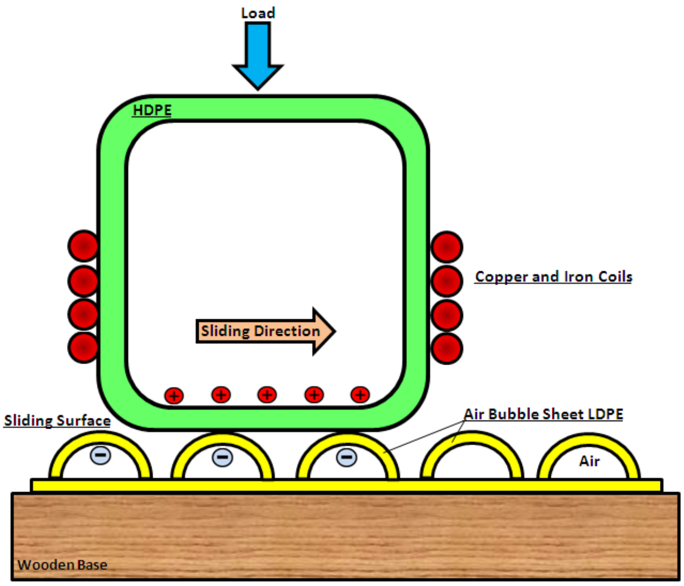


**Fig. 1 Single layer air bubble sheet of PE.**

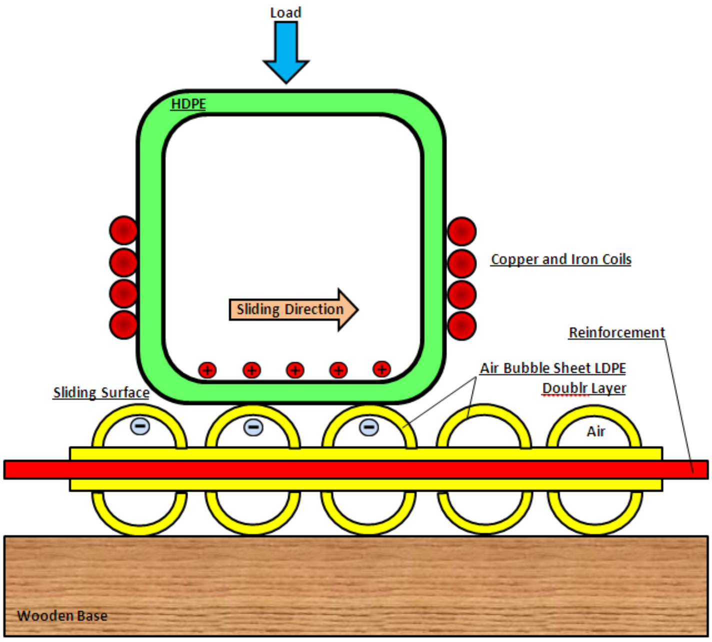


**Fig. 2 Double layer air bubble sheet of PE.**

## RESULTS AND DISCUSSION

**ESC generated on HDPE sliding against LDPE, Fig. 4, showed increasing trend with increasing the sliding distance. HDPE fitted by steel wires recorded higher values followed by copper wires, while HDPE free of wires displayed the lowest ESC. That behavior can be explained on the basis that when an electric field and a wire move relative to each other, a voltage is induced. Besides, strong electric field produces high voltages. In the present work, steel and copper wires are wrapped HDPE, and the electric field is generated from ESC generated from friction. It is expected that high voltage will be generated on the sliding surface, where steel wires generate relatively**

higher voltage. Besides, it is known that by changing the magnetic field around a conductor a voltage will be induced by electromagnetic induction. It is known that sliding of materials as well contact and separation cause the charge transfer to build up on the sliding surfaces forming double layer of ESC on the sliding surfaces which are responsible for generation of the electric field that induces electric current flowing in the conductor. The strength of the electric field inside the matrix is proportional to how much charge is generated on the friction surface. The induced current creates an induced magnetic field. The magnetic field around a straight conductor is directly proportional to the current value and inversely proportional to the distance from the conductor. The significant ESC increase in the presence of steel and copper wires confirms the presence of the magnetic field around them. The counterface (LDPE) gained higher negative ESC values reached -7800 volts at 200 mm sliding distance, Fig. 4, in the presence of steel wires as result of the magnetic field.

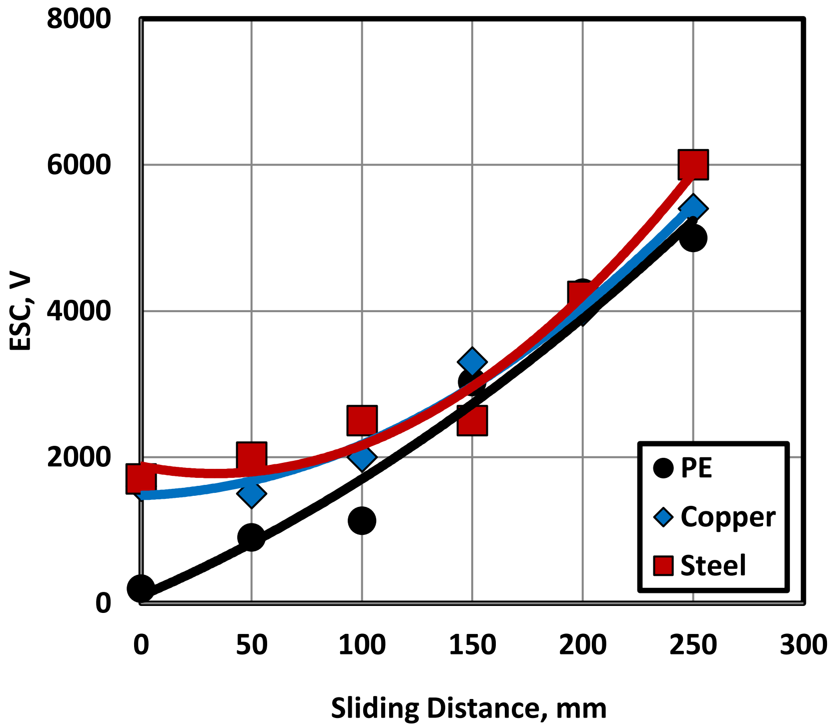


Fig. 3 ESC generated on HDPE sliding against LDPE.

When the LDPE sheets were reinforced by CF drastic decrease of ESC was observed, Fig. 5, where the highest ESC reached 4800 volts for HDPE wrapped by steel wires instead of 6000volts observed for unreinforced HDPE, Fig. 3. This observation indicated that ESC generated from friction can be reduced by leaking through metallic conducting sheet inserted between the two LDPE layers. ESC generated on LDPE showed the same trend, Fig. 6, where HDPE recorded -2200 volts then the values increased for copper and steel wires to -2400 and 3100 volts respectively.

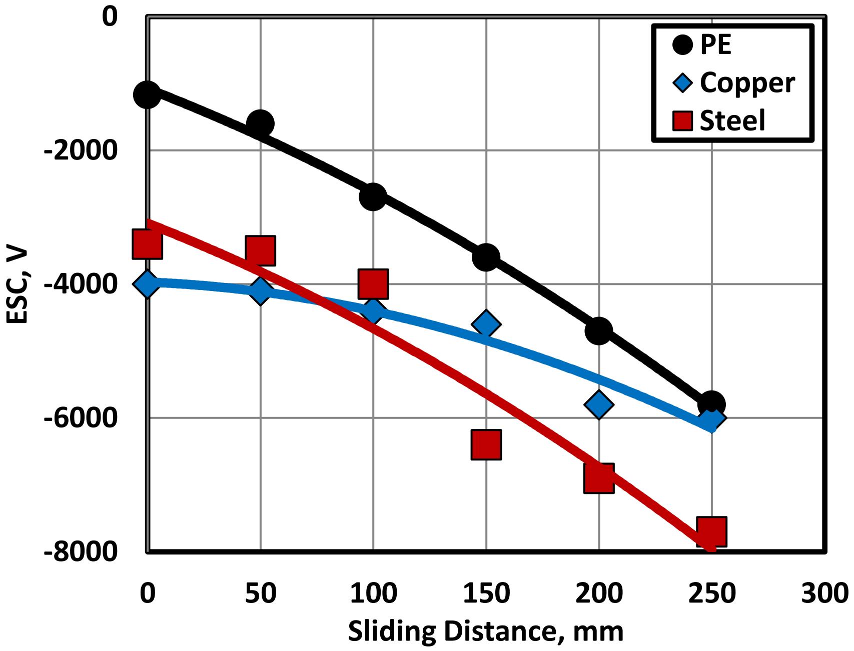


**Fig. 4 ESC generated LDPE on sliding against HDPE.**

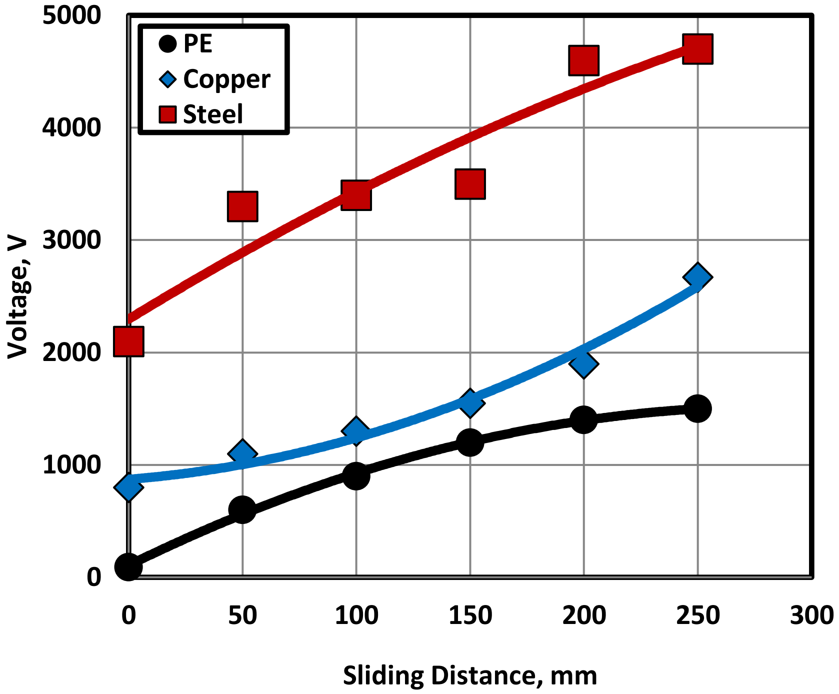


**Fig. 5 ESC generated on HDPE sliding against LDPE reinforced by CF.**

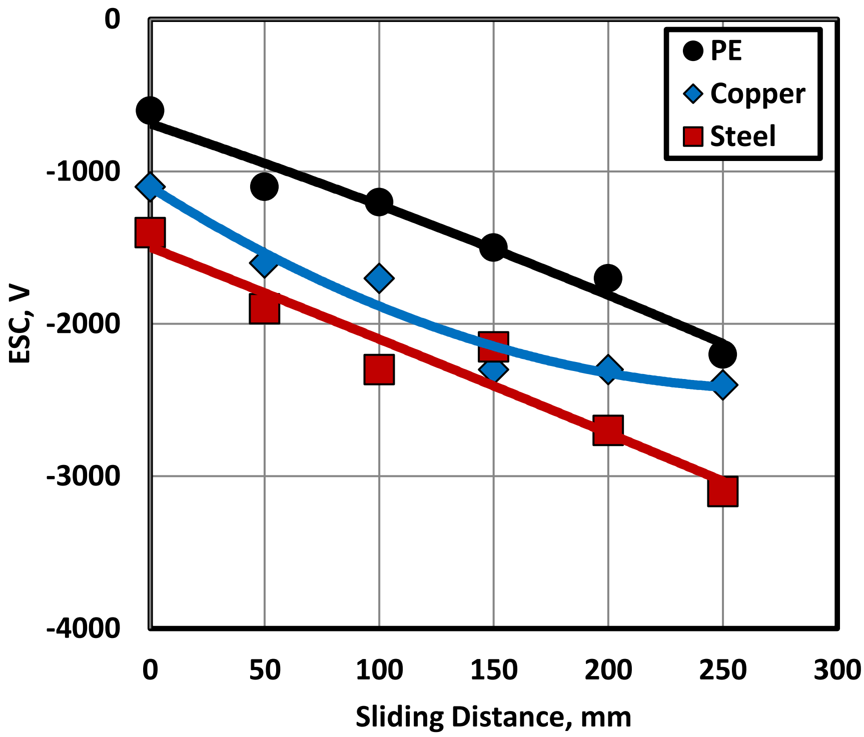


**Fig. 6 ESC generated on LDPE reinforced by CF sliding against HDPE.**

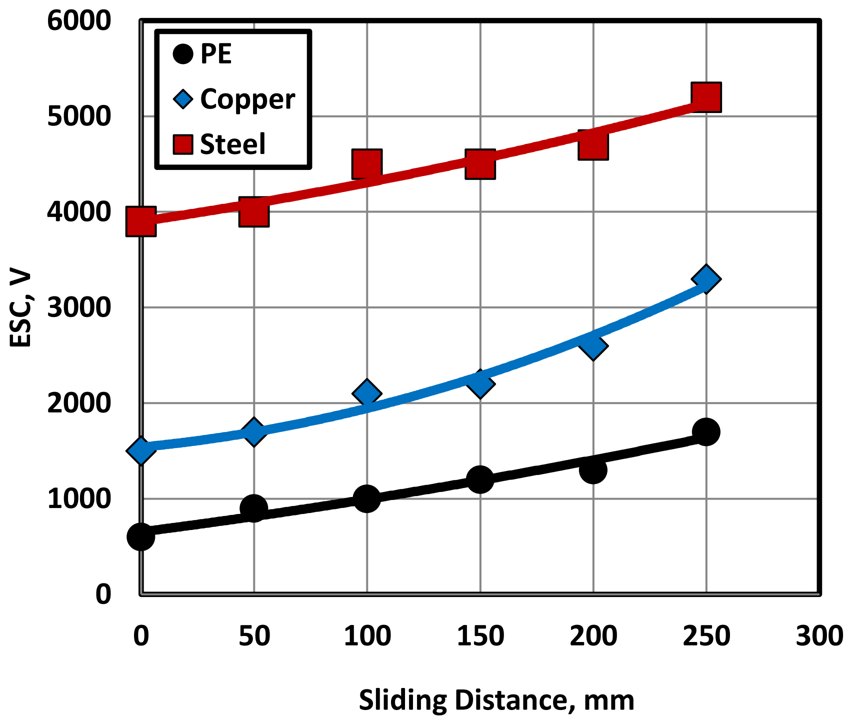


**Fig. 7 ESC generated on HDPE sliding against LDPE reinforced by aluminium film.**

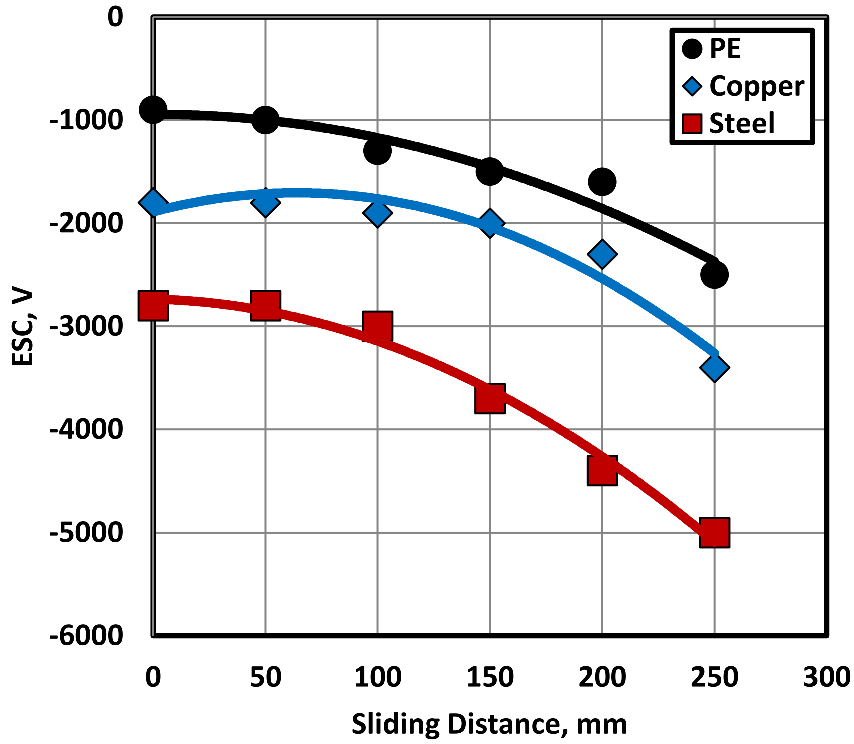


**Fig. 8 ESC generated on LDPE reinforced by aluminium film sliding against HDPE.**

**ESC generated on the surface of HDPE after sliding against LDPE reinforced by aluminium film is shown in Fig. 7. As the sliding distance increased ESC increased. The highest value of charge is observed at 200 mm sliding distance. When the iron coil was wrapped to HDPE the highest ESC was measured (5100 volts), while in the absence of the coil the lowest ESC value (1700 volts) was observed. ESC gained by LDPE reached -5000 volts after 200 mm distance for the steel coil, Fig. 8, indicating the influence of the iron wires. Those value are relatively higher than that observed for CF reinforced LDPE. ESC generated during contact and separation as well as sliding of the tested materials can play a major role in adhesion energy and alter friction by the effect of the trapped charges and, consequently on the presence of surface defects introduced during friction. Based on the values of ESC, it is shown that CF were performed better that Al film in leaking ESC rom the sliding surfaces.**

**ESC generated on HDPE sliding against LDPE reinforced by CF textiles is illustrated in Fig. 9, where steel wires represented the highest values. This may be attributed to the fact that the strength of the electric field crossing the sliding surface is proportional to how much charge is generated. Faraday indicated that the change of the flux over time may induce a current in a conductor and thus create a source of EMF (voltage, potential difference). If an electric conductor is moved through a magnetic field, or a magnetic field moves through the conductor, electric current will be induced and flow into the conductor. The induced current creates an induced magnetic field. The Magnetic field is much influenced by steel wires due to its magnetic property. The same trend was observed for ESC generated on LDPE reinforced by CF textiles, Fig. 10.**

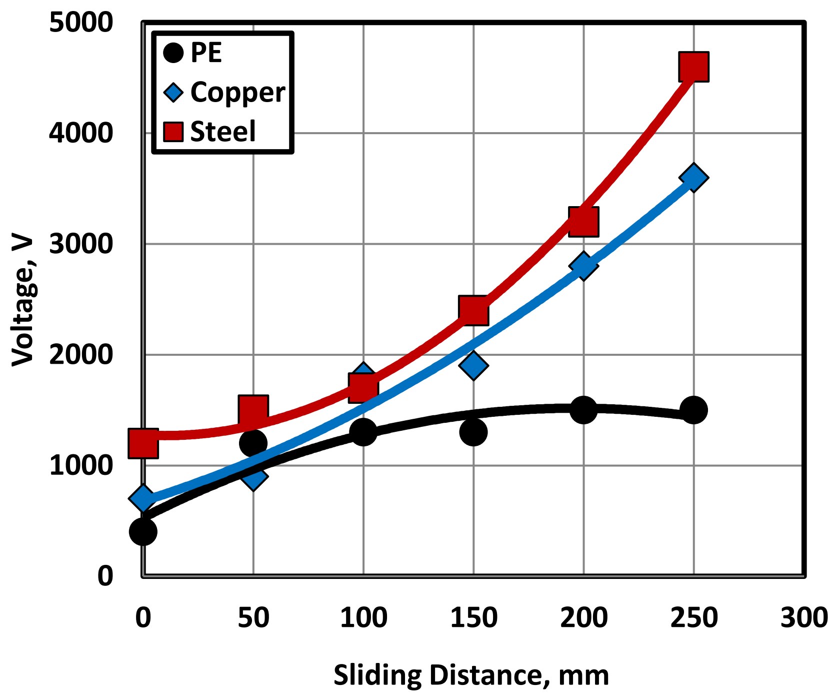


**Fig. 9 ESC generated on HDPE sliding against LDPE reinforced by carbon fibres textiles.**

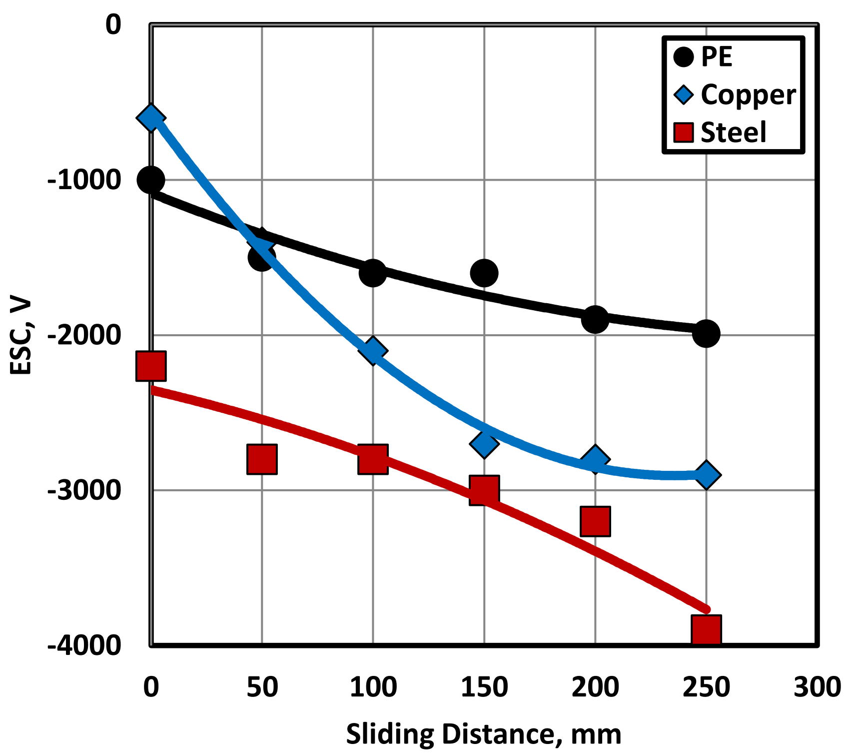


**Fig. 10 ESC generated on HDPE sliding against LDPE reinforced by CF textiles.**

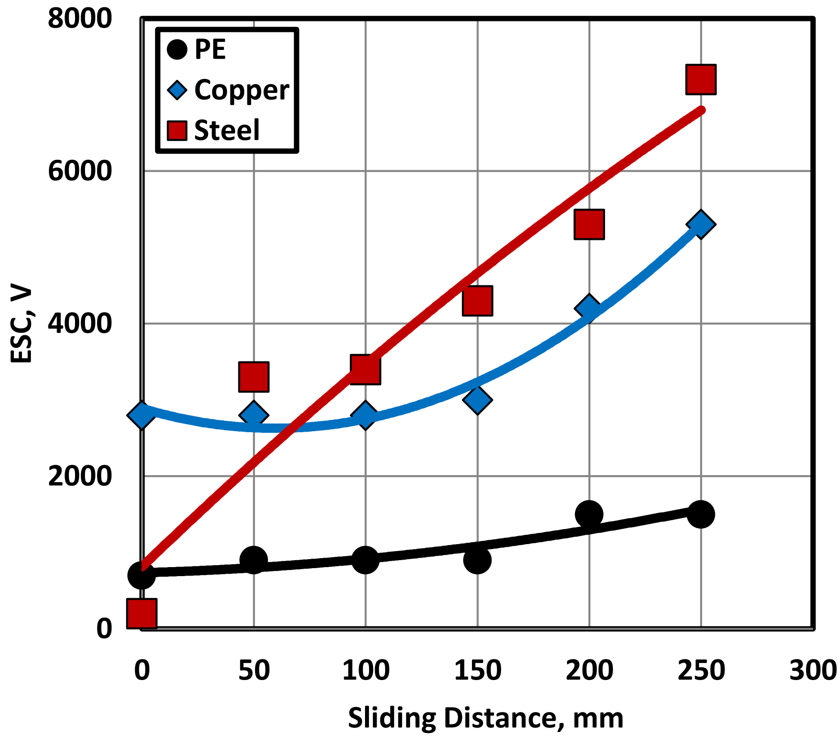


**Fig. 11 ESC generated on HDPE sliding against LDPE reinforced by stainless steel sheet.**

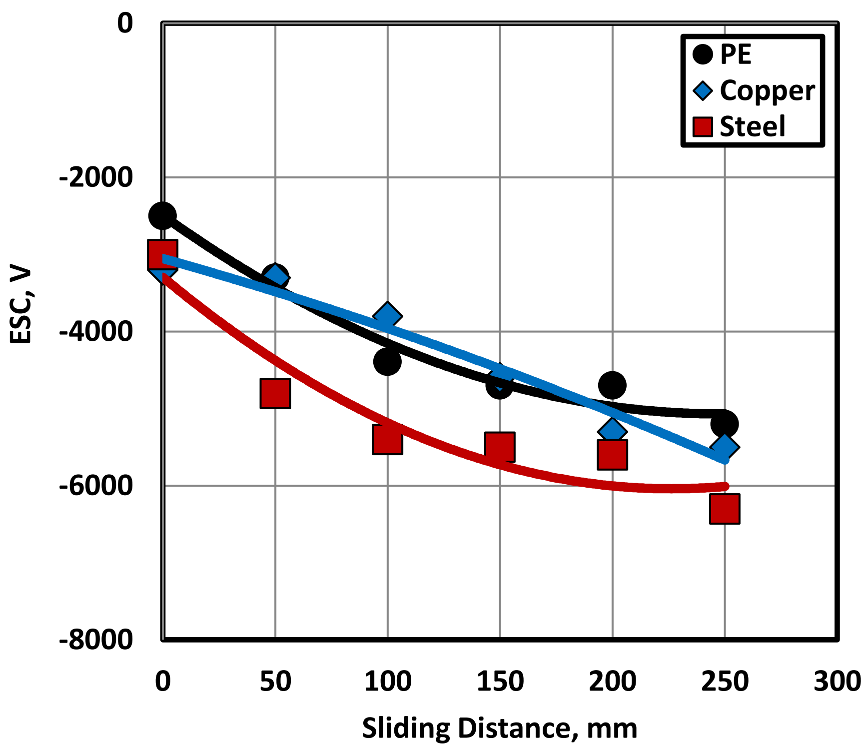


**Fig. 12 ESC generated on HDPE sliding against LDPE reinforced by stainless steel sheet.**

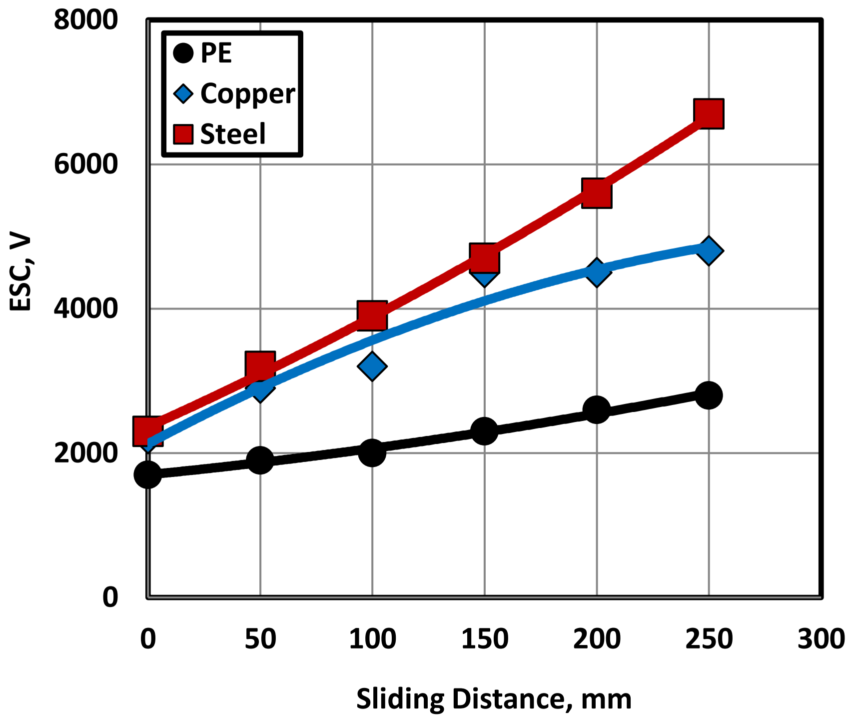


**Fig. 13 ESC generated on HDPE sliding against LDPE reinforced by copper textiles.**

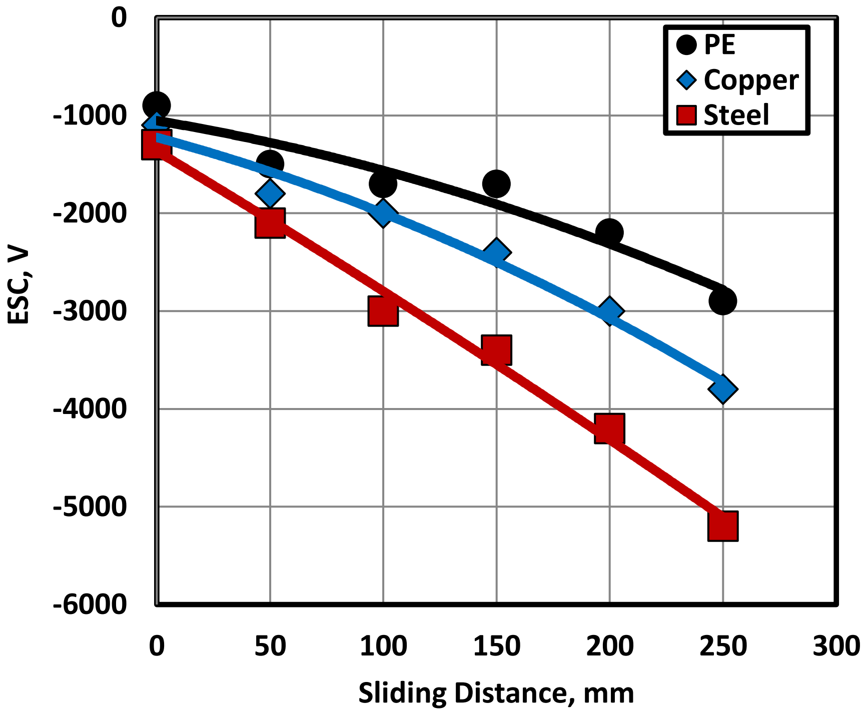


**Fig. 14 ESC generated on HDPE sliding against LDPE reinforced by copper textiles.**

**The influence of reinforcing LDPE by stainless steel sheet on ESC generated on the sliding surfaces is discussed in Figs. 11, 12. It is clearly seen that as ESC increases with increasing sliding distance. The highest values of ESC were 7200 and -6200 volts on the surfaces of HDPE and LDPE respectively in the presence of the steel wires. Those composites showed the highest ESC values. That behviour can be interpretted on the**

basis that the double layer of ESC generated on the sliding surfaces of HDPE and LDPE would generate an E-field. Presence of steel and copper wires would generate extra ESC on the sliding surfaces due to the generation of electric field which affected the sliding surfaces by extra electric charge.

When LDPE was reinforced by copper textiles, ESC generated on HDPE sliding against LDPE reinforced by copper textiles displayed relatively high values, Figs. 13 and 14. Generally, ESC increased proportionally with increasing the sliding distance. The generation of ESC is from the contact of the sliding surfaces which accelerates the electron exchange. ESC charge will be gained by each of the surfaces. Based on the rank of the two sliding materials in the triboelectric series, one surface would gain negative charge while the other would gain positive charge. Reinforcing HDPE by iron wires generated higher ESC than the other tested composites. It seems that the intensity of the E-field increased in the presence of iron wires. The E-field is considered as the total electric force resulted from the charge, where the distribution of charges controls the generation of electric field. ESC measured on the PE surface reached 6800 volts after 200 mm sliding distance in the presence of iron wires. It seems that reinforcing PE by iron wires and the generation of ESC on the space surrounding the wires generates a magnetic field whose intensity was higher than that supposed for copper wires.

## CONCLUSIONS

1. ESC generated on HDPE sliding against LDPE showed increasing trend with increasing the sliding distance. HDPE wrapped by steel wires recorded higher values followed by copper wires, while HDPE free of wires the lowest ESC.
2. ESC decreased when the LDPE sheets were reinforced by CF.
3. ESC can be reduced by reinforcing LDPE layers by conducting sheet.
4. ESC generated on the surface of HDPE after sliding against LDPE reinforced by aluminium film was higher than that observed for CF reinforced LDPE.
5. After HDPE free of wires, the highest value of ESC generated on the LDPE reinforced by steel sheet followed by copper textiles.

## REFERENCES

1. Yam K. L., "Encyclopedia of Packaging Technology", John Wiley & Sons, (2009).
2. Ali A. S., Khashaba M. I., "Effect of Copper Wires Reinforcing Polyethylene on Generating Electrostatic Charge", Metall, 71, 6/2017, pp. 237 – 241, (2017).
3. Rehab I. A., Mahmoud M. M., Mohamed A. T. and Ali W. Y., "Electric Static Charge Generated from Sliding of Epoxy Composites Reinforced by Copper Wires against Rubber", EGTRIB Journal, Vol. 12, No. 3, July 2015, pp. 28 – 39, (2015).
4. Rehab I. A., Mahmoud M. M., Mohamed A. T. and Ali W. Y., "Increasing the Safety of Walking against Epoxy Floorings Reinforced by Metallic Wires", KGK, 05 2016, pp. 54 – 59, (2016).
5. Rehab I. A., Mahmoud M. M., Mohamed A. T. and Ali W. Y., "Effect of Electric Static Charge on Friction Coefficient Displayed by Sliding of Rubber Sole Against Epoxy Floor Reinforced by Copper Wires", EGTRIB Journal, Vol. 12, No. 4, October 2015, pp. 40 – 52, (2015).
6. Rehab I. A., Mahmoud M. M., Mohamed A. T. and Ali W. Y., "Frictional Behaviour of Epoxy Reinforced Copper Wires Composites", Advances in Materials Research, Vol. 4, No. 3, pp.165 - 177, (2015).
7. El-Sherbiny Y. M., Samy A. M. and Ali W. Y., "Electric Static Charge Generated from Bare Foot and Footwear Sliding Against Flooring Materials", Journal of the Egyptian Society of Tribology, Vol. 11, No. 1, January 2014, pp. 1 – 11, (2014).

**8. Alahmadi A., "Triboelectrification of Engineering Materials", Journal of the Egyptian Society of Tribology, Vol. 11, No. 1, January 2014, pp. 12 – 23, (2014).**
**9. Alahmadi A., "Influence of Triboelectrification on Friction Coefficient", International Journal of Engineering & Technology IJET-IJENS Vol:14 No:05, pp. 22 – 29, (2014).**
**10. Youssef Y. M., Khashaba M. I. and Ali W. Y., "Electrostatic Charge Generated from the Sliding the Football on the Gloves of the Goalkeeper", EGTRIB Journal, Vol. 13, No. 4, October 2016, pp. 41 – 52, (2016).**
**11. Ali A. S., Youssef Y. M., Khashaba M. I. and Ali W. Y., "Electrostatic Charge Generated From Sliding of Polyethylene Against Polytetrafluoroethylene", EGTRIB Journal, Vol. 14, No. 3, July 2017, pp. 34 – 49, (2017).**