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# INVESTIGATION OF THE ELECTROSTATIC CHARGE GENERATED FROM FABRICS SLIDING ON PMMA / HDPE COMPOSITES

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## ABSTRACT
The recent attention that the electrostatic charge (ESC) has gotten for this decade leads to several studies and investigations for polymeric reinforced composites mechanical applications beside the ESC observation. Polymethyl methacrylate (PMMA) and High-density polyethylene (HDPE) have a proposing demand due to their own engineering applications. There are several engineering applications that lead to more interest in this type of blended materials. In the present research, the behavior of ESC generated from sliding of the composites (HDPE-PMMA) on different fabrics made of polyester (PET) and cotton is investigated. In addition, the coefficient of friction has been studied. The relation between the coefficient of friction and the electrostatic charge is stated. The results show a remarkable dependence on electrostatic charge (ESC).

## KEYWORDS
Electrostatic charge (ESC), Coefficient of Friction, HDPE, PMMA, Textile.

## INTRODUCTION
Plastics are considered the most important and widely used materials in our modern life and advanced industry for the last years. Their usage in various industrial applications is one of the reasons for this great popularity due to the tremendous range of characteristics exhibited by plastics, besides their ease of processing. A new approach in polymer science and technology has emerged recently. These polymers and their composites must show good performance under active working conditions imposed by the requirements of a specific engineered application, [1].

Blending different polymers play an important role in approach of production for tailoring textile products with a required material property. the efficiency of polymer blends depend on their individual properties of the components, as well as how they are arranging in space and whether the two polymers are miscible or exist as a single phase, most blends of high molecular weight polymers exist as two-phase materials, [2 - 4].

On another hand, harvesting the green renewable energy resources in a nominal path is a challenge and essential need for covering the consequences of fossil energy, [5]. In addition, for household appliances in remote locations, harvesting locally accessible energy is more desirable than constructing power plants that require significant costs and heavy infrastructure [5 - 8].

**Nevertheless, what batteries con offered for the modern engineering application is limited life by storage capacity. As the amount of the electronics increases, it has become much more difficult the replacement, manages, and/or recycling of the huge number of batteries, [9 - 11].**

**The triboelectric effect is a type of contact and separation for surfaces electrification, related to which a type of material would be electrically charged after it comes into frictional or contact situation with another dissimilar material in its natural electrical charge. Well, It is a natural effect for any material and a general cause of everyday conditions. The triboelectric series paves the path for future investigation in this field, [12 - 16].**

**The discussion and investigation for the principle of this phenomenon are taking place in many articles, [17]. Triboelectric charging could be gained from contact between surfaces. The recent evidence from a microscopic investigation contacts charging can result from material transfer delivers a good reason to study how to contact surface charging is affected by these factors. Previous studies find that the compacting of two polymers results in the transfer of lower layers than would result from light contacts. Different layers can have typically opposite compositions due to the polymer being typically not homogeneous, so contact and separated surface are almost related. This could account for charge transfer between similar polymers, especially in non-similar contacts in which the frictional force on one polymer differs from that on the other, so that material from different depths is transferred.**

**One of these observations is the long-standing ranking of materials in triboelectric series according to their propensity to charge positively or negatively upon surface contact, even though numerous dissimilarities were found. Some sets of materials form cyclic series which strongly suggest that more than one mechanism is involved in the charge transfer. Relationships have long been observed between different signs of charging and some physical properties. Polymers having strong tendencies to charge positively that have high dielectric constants, are highly polar and consistent with the fact that water has a high dielectric constant value, [13, 14].**

**Several materials are ranked in the triboelectric series according to their ability to gain or lose electrons, which reflects the physical property of the contact materials. Static electricity appears when there is an overabundance of positive or negative charges on an object's surface by stroking certain materials together. The position of the material in the triboelectric series affects the evaluation of how the charges will be substituted. Typically, the existence of static electricity would be unwanted because it can result in product failure or a serious safety hazard caused by an electrostatic discharge. Alternatively, the triboelectric series can be used to choose materials that will reduce static charging to avoid discharge or electrostatic attraction. Triboelectrification has established an interest recently as it has been used for triboelectric nanogenerators (TENGs) fabricating, which have been used for converting tiny mechanical energy into electricity for energy gathering, [7].**

**Moreover, it is worthy to mention that the biomechanical energy of man is characterized by fluctuating movement during the daytime, and effective utilization of such energy cannot be attained by energy gathering methods and technologies. However, reporting a self electricity charge power system for operation of mobile electronics using nonstop biomechanical human energy [9]. This electrical self-charging unit can be widely applied as a reliable power source for continuously driving huge conventional electronics, such as wearable watches, thermometers, scientific calculators, and low power communication systems, which indicates the instantaneous and broad applications in personal sensor systems and the internet of things, [18]**

It is well known that The effect of electrostatic charge is of considerable all industrial importance in terms of safety and avoiding the predicted damage to manufactured goods for any materials. Especially when it comes to igniting flammable vapors, for petroleum products For bulk fuel deliveries and aircraft fueling, at the foundation connection is created between the vehicle and the receiving tank before opening the tanks. It Means have to be provided to discharge static from carts which may carry volatile liquids, flammable gasses, or oxygen in hospitals. Furthermore, In the case of textile manufacture, this can lead to a permanent grimy mark where the cloth comes in contact with dust accumulations held by a static charge which leads to more work to clean the surfaces, [5, 8, 10, 16, 18].

In the present work, ESC generated from sliding of the tested composites (HDPE-PMMA) on different fabrics made of blend of polyester (PET) and cotton is investigated. Besides, the coefficient of friction has been studied, where the relation between the coefficient of friction and the ESC is determined.

**EXPERIMENTAL**

The test rig shown in Fig. 1 is used to measure the coefficient of friction (μ) by using the load cell output connected to the Arduino program linked to PC. The load cell signal output was calibrated with normal load in to produce the coefficient of friction value, see Fig. 2. which represents the wiring diagram for Arduino with the load cell. Moreover, electrostatic charge in Dc Volts was measured by (Ultra Stable Surface DC Voltmeter) was applied to measure the electrostatic field, see Fig. 3.

Moreover, there is a vice used to control the movement of fabric in the perpendicular direction to the normal Force as illustrated in Fig.1 back and forth as one stroke. However, using two copper plates is essential can identify and measure the output values of electrostatic charge. The description of the electrostatic charge generated is shown in Fig. 4 as a sliding mechanism to charge the materials that were tested.

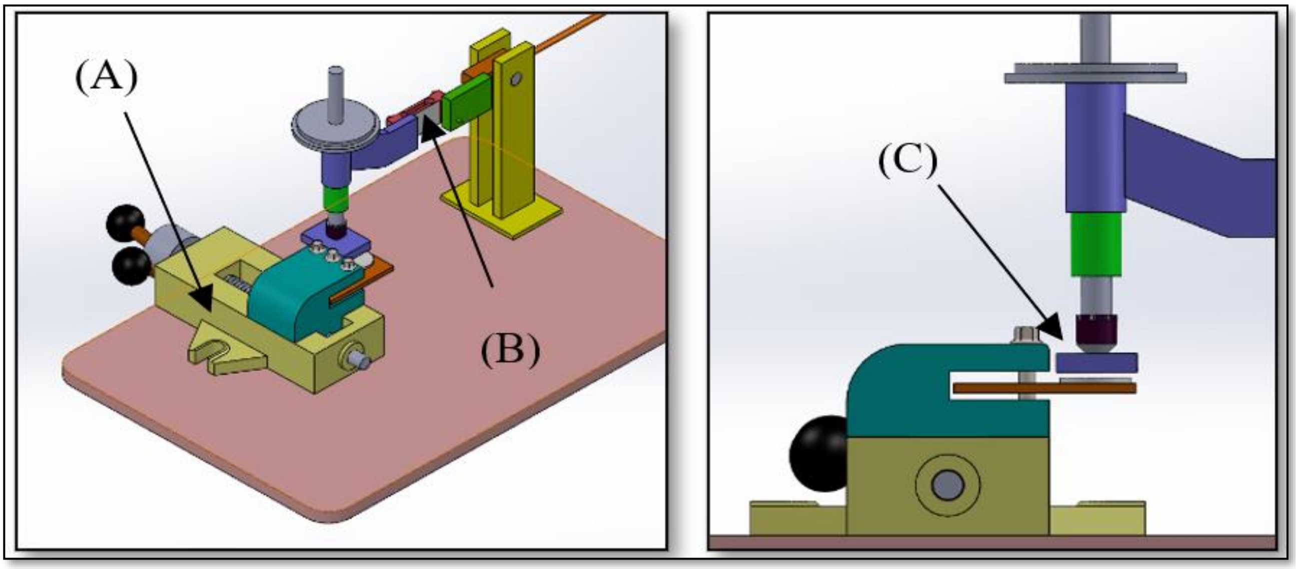



Fig. 1 Test Rig for measuring electrostatic charge and coefficient of friction. (A) Vice, (B) Load cell, and (C) Position of the specimen.

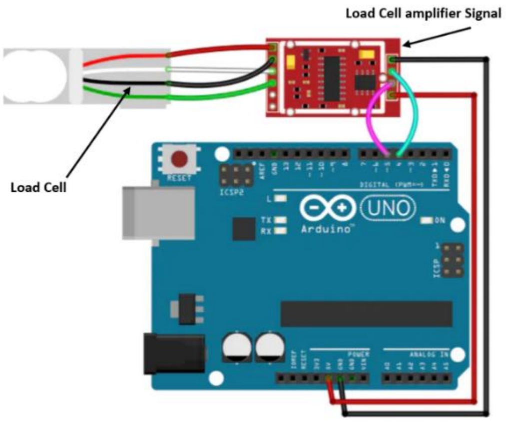



Fig. 2 Wiring diagram for load cell Sign


Fig. 3 Surface DC voltmeter.

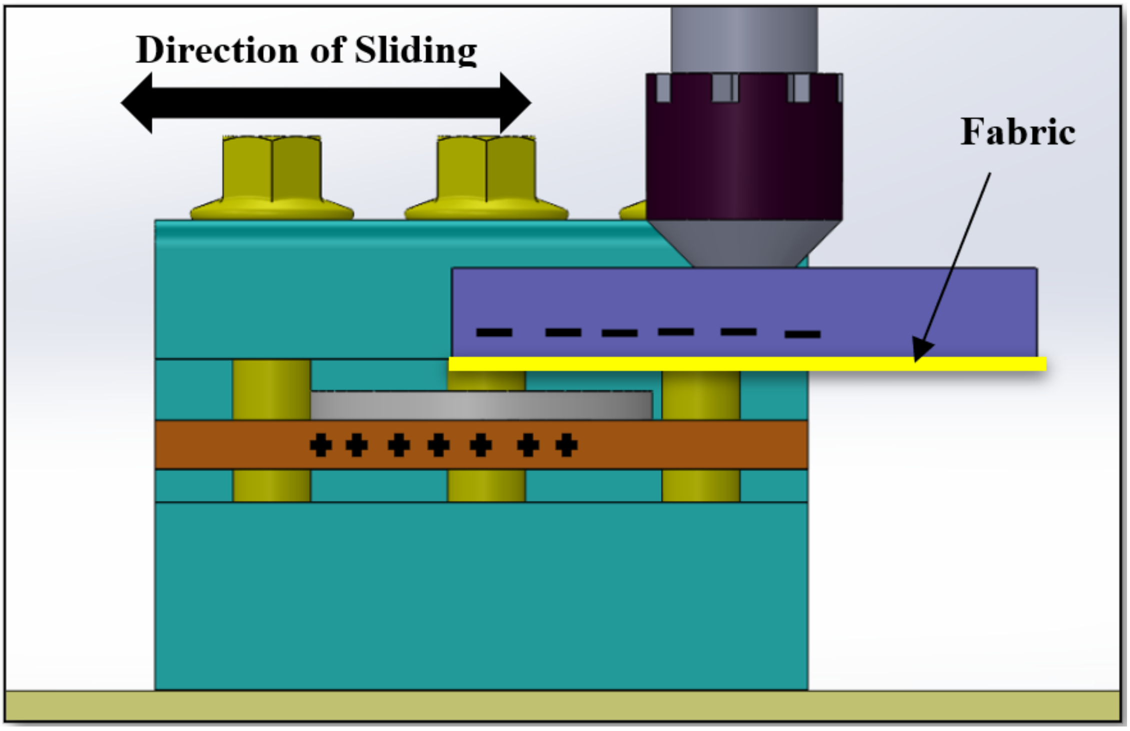



Fig. 4 The mechanism of electrostatic charge built-up on the test rig

**The fabrics were chosen in different cotton - polyesters percentage present in the all fabric as (A, B, C, D & E) arranged in ascended for the present of cotton fabric respectively, as shown in Fig.5. The normal load was considered as a parameter in electrostatic charge and coefficient of friction investigations as (2, 4, 6, 8, 10) newtons.**

**Figure 6 (a) shows the physical form that HDPE was delivered as a powder. The PMMA material was supplied as a cold cure product, which has been shown in Fig.6 (b). preparing of samples takes place in a wood mold as shown in Fig.7. the mold consists of six cavities distributed equally in dimension (80 mm* 40 mm) with a thickness (3 mm). the percentage of blending was selected to be (95-90-85-80 % PMMA) and the remaining composition is HDPE. Moreover, there are two pure specimens of PMMA & HDPE.**

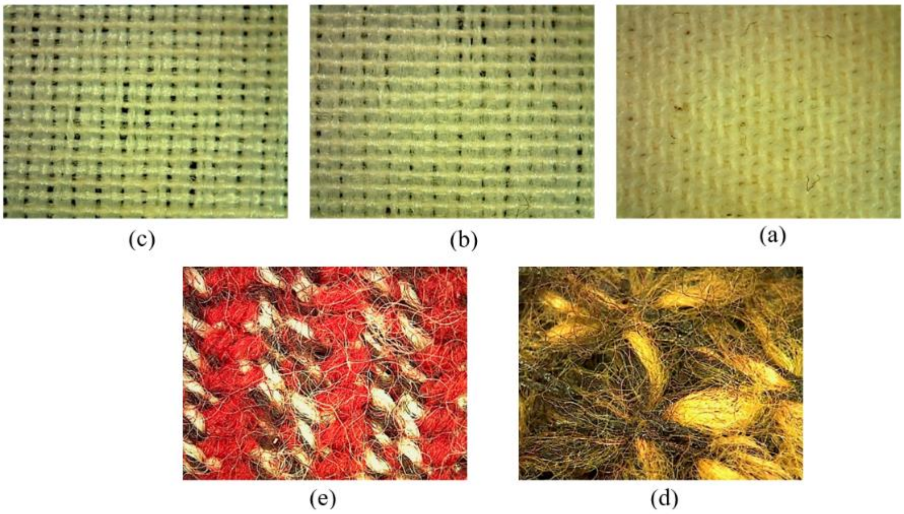



**Fig. 5 Optical Microscopic Investigation of the tested Fabris.**


**Fig. 6 (a) HPDE  Powder, (b) PMMA (cold cure).**

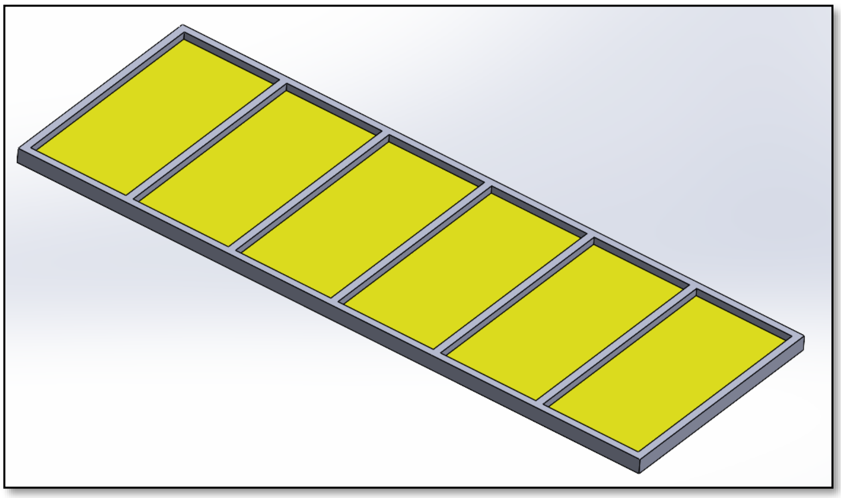


**Fig. 7 The Mold Used for Specimen Preparation.**

## RESULTS AND DISCUSSION

**Investigation of electrostatic charge is relative to certain parameters such as coefficient of friction, normal load, and types of contacts surfaces. However, there are a good number of scientific articles that present the depends on the coefficient of the friction on the electrostatic charge. Triboelectricity is formed whenever two solids rub, slide or roll on each other and the resulting charges on both surfaces contribute electrostatic forces to their mutual interactions attraction between oppositely charged surfaces should push the solids together thus requiring additional pull to slide one solid on the other, according to Amontons' law[8].**

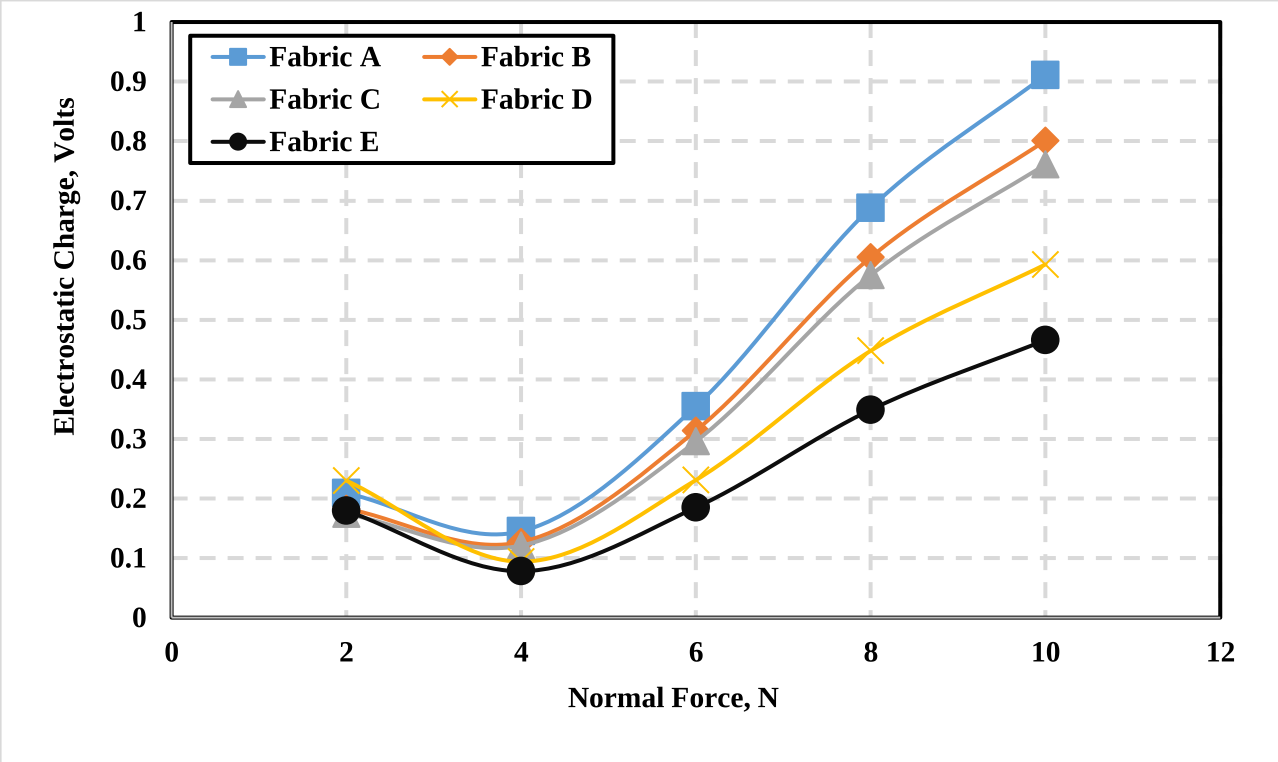



**Fig. 8 The relation between normal load and electrostatic charge for HDPE and different fabrics.**

**Figure eight describes the relation between electrostatic charge in volts and normal load for the HDPE sample. It is observed clearly that there is a slight increase in the value of recorded electrostatic charge with a normal load. Besides, point 4N shows a small decrease for all fabrics types for an electrostatic charge. Besides, it can be observed that fabric (A) represents the highest value of electrostatic charge due to a lower percentage of polyester. On another hand, the highest value of (ESC) was recorded at 10N normal load as shown in the figure.**

**a remarkable relation. for the first three-point of the (ESC) data values could be described as a steady situation. On the other hand, there is an increase in value of volts that reach one volt and exceded in Fabric (B) change for 8N and 10N.**

**Furthermore, figure nine that represent the values which harvesting from sliding of blended composite that consist form (90%PMMA-10%HDPE). it can be concluded from Fig. 11 fabric (E) recorded the highest value of (ESC) at normal load 10N.beside, that there is a slight decrease in the amount of generated electrostatic charge compared with other previous samples.**

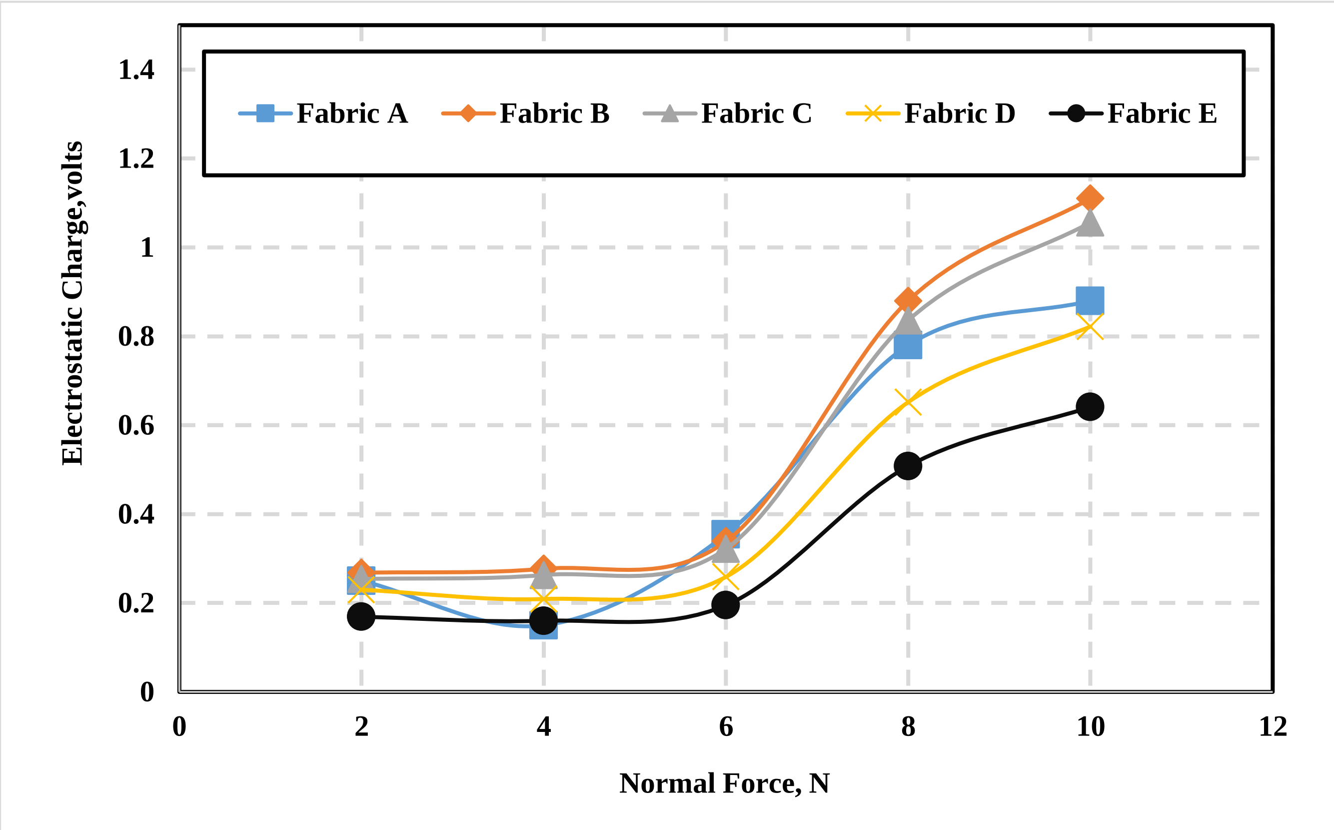



**Fig. 9 Normal load vs. Electrostatic charge for PMMA and different fabrics.**

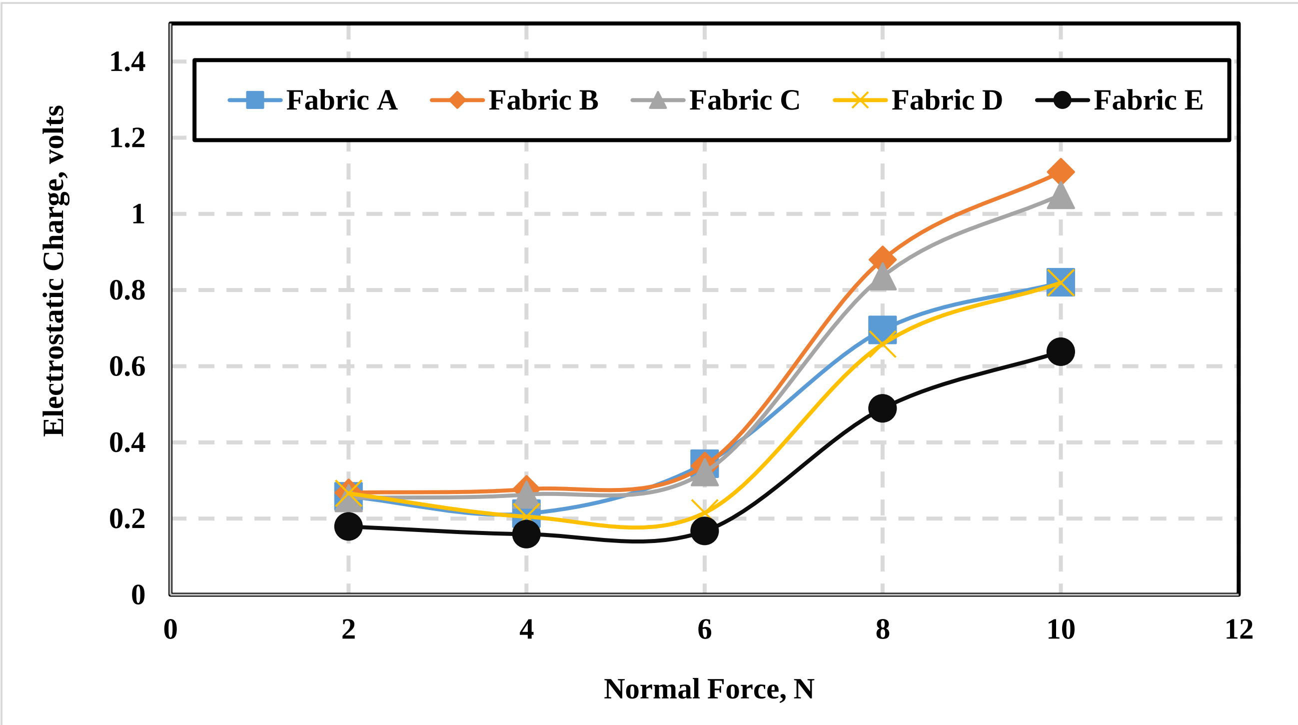



**Fig. 10 Electrostatic charge for 95% PMMA- 5% HDPE and different fabrics at different normal loads.**

And in the same context, the relation between (ESC) and normal load for blended PMMA 95%-HDPE 5%) versus the different fabrics is shown in Fig.10. (ESC) that generated form sliding of the sample on vires types of fabrics represents

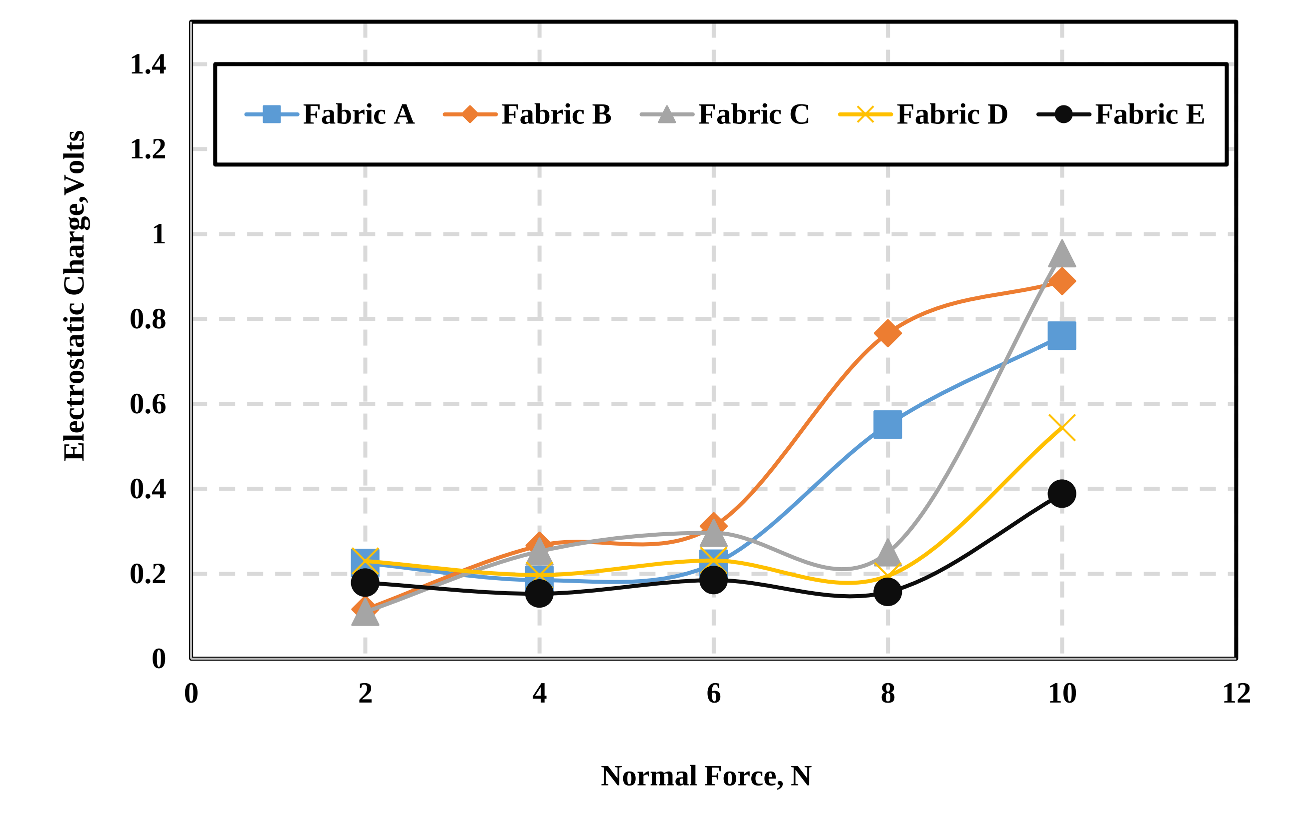



**Fig. 11 The relation between normal load and Electrostatic charge for 90%PMMA- 10% HDPE and different fabrics.**

**However, by investigating the two following figures (12-13) which describe the relation between electrostatic charge and normal loads for the last two samples (85%-80%) PMMA. It can be observed clearly that there is a dramatic decrease in the values of DC volts that generate from triboelectric motion that occurs from samples sliding. By comparing the two figures, for fabric (B), it can be concluded the reduction in the value of (ESC) to be near 0.5 DC volt. Furthermore, with a general sight for all previous illustrations, it seems that the increase of HDPE reduces the volts that generate from the slid mechanism.**

**The relation between coefficient of friction and normal force, for unreinforced samples HDPE & PMMA is illustrated in Fig.14. and Fig.15. it was concluded that any type of fabric could not exceed the value of one coefficient of friction for fabric (E) for all normal load 2N used in the study. Moreover, there is a remarkable decrease in the value of (μ) with increasing the normal load for tested fabrics. Fabric (D) represents the highest value that can be recorded for (μ). However, normal load 10 N registered the lowest coefficient of the friction to be (0.2).**

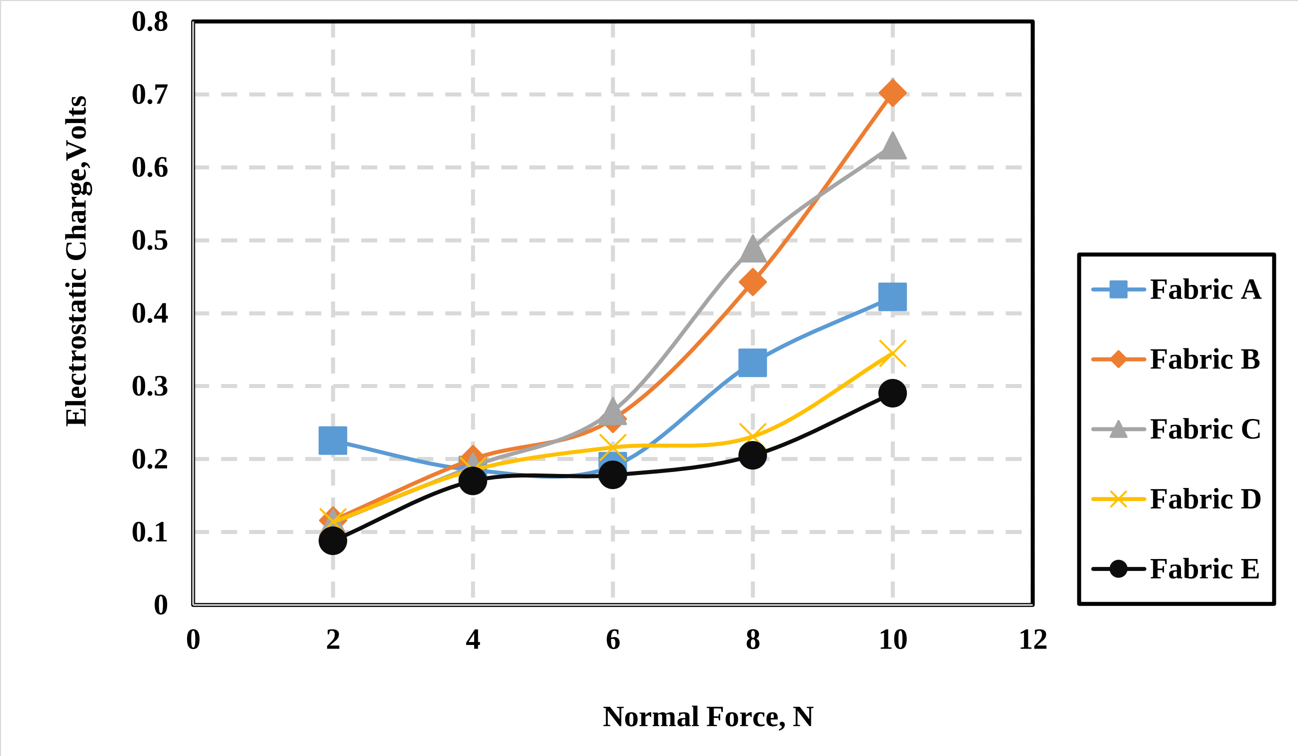



**Fig. 12 The values of Electrostatic charge for 85%PMMA- 15% HDPE and different fabrics.**

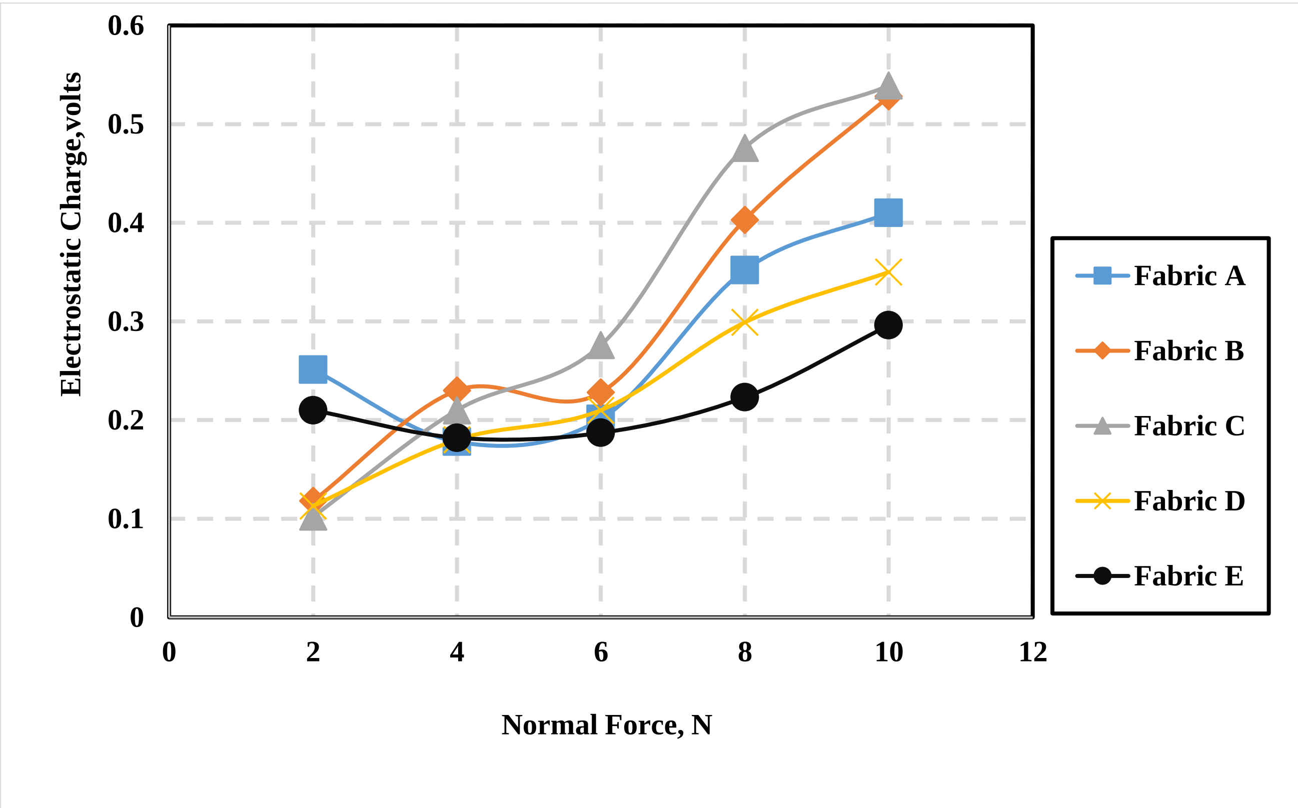
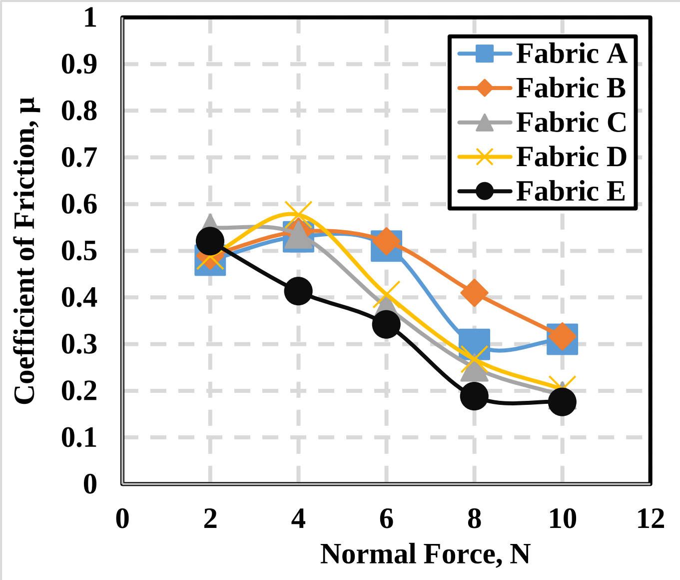



**Fig. 13 The relation between normal load and Electrostatic charge for 80%PMMA- 20% HDPE and different fabrics.**



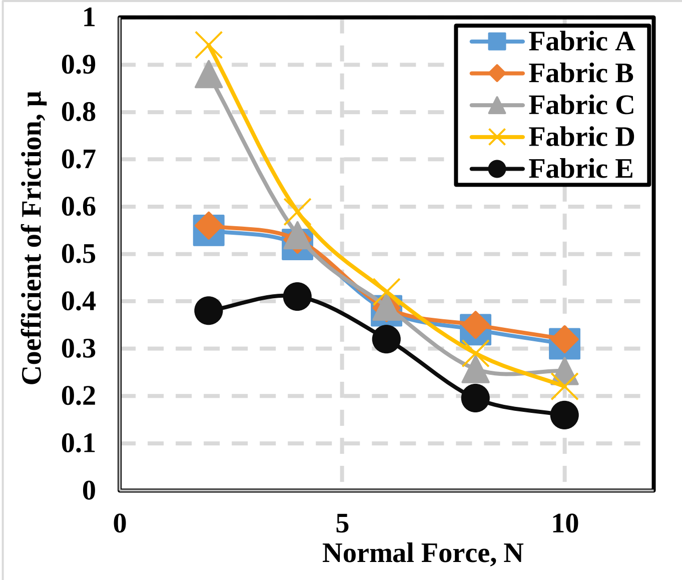
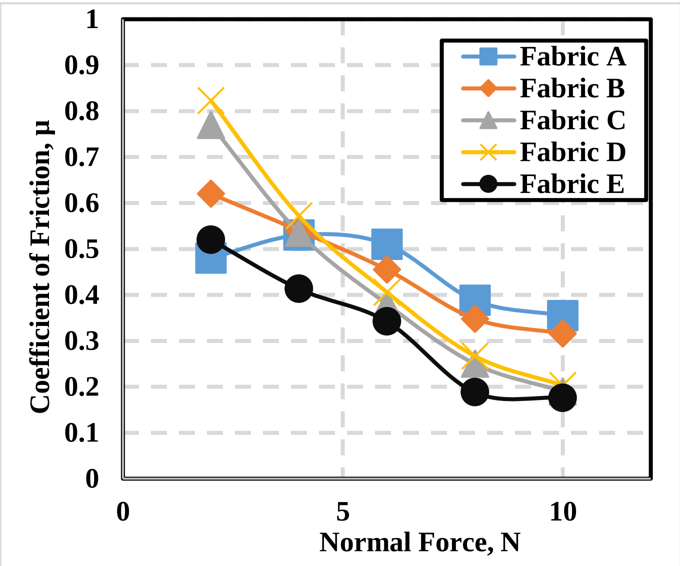




**Fig. 14 The relation between normal load and Coefficient of fraction for HDPE and different fabrics.**

**Fig. 15 The relation between normal load and Coefficient of fraction for PMMA and different fabrics.**



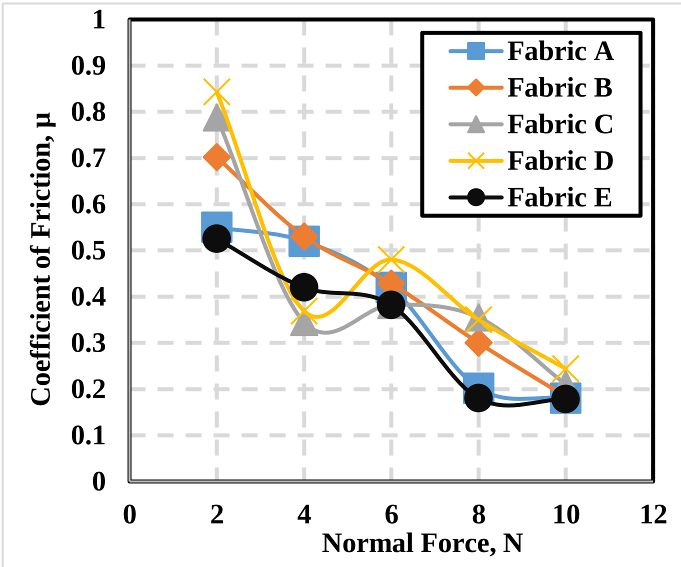




**Fig. 16 The relation between normal load and Coefficient of fraction for (95 % PMMA-5% HDPE) and different fabrics.**

**Fig. 17 The relation between normal load and Coefficient of fraction for (90 % PMMA-10 % HDPE) and different fabrics.**

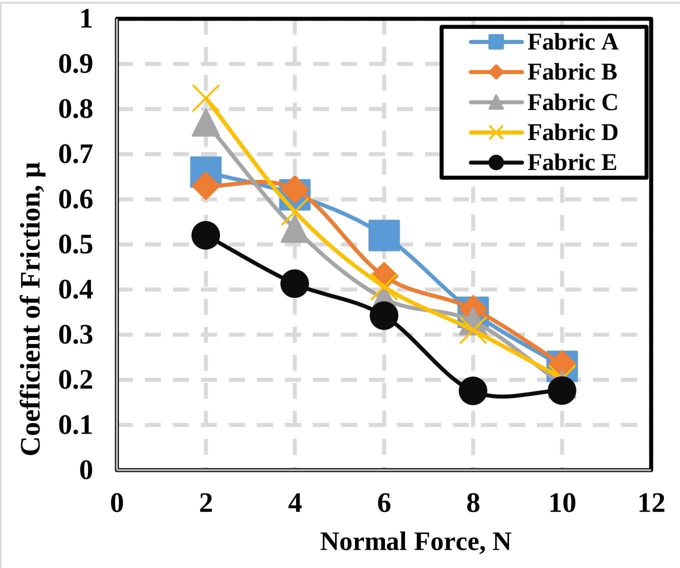



Fig. 18 The relation between normal load and Coefficient of fraction for (85%PMMA-15%HDPE) and different fabrics.

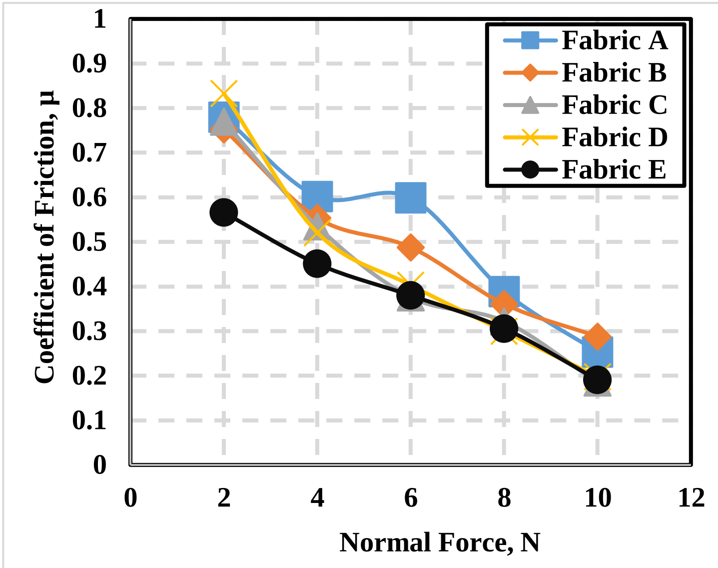



Fig. 19 The relation between normal load and Coefficient of fraction for (80%PMMA-20%HDPE) and different fabrics.

Nevertheless, the deeper investigation for (COF) in the present study. Figures (16,17,18&19) describe the trend between the coefficient of friction and normal load for other percentages of blended (PMMA-HDPE). Generally, the obvious trend is the decrease in (COF). The coefficient of friction drastically decreased with increasing the normal force. Moreover, It was observed that the type of fabrics influenced the friction values, whereas the weave size and the thickness of the strings increased, the friction coefficient decreased. The friction decrease with increasing the normal force may be explained on the basis that the load is ironing the fabrics, and consequently, the friction of the fibers is drastically reduced.

## CONCLUSIONS

From present investigation it can be concluded the followings:
1. The electrostatic charge value depends on the normal load.
2. Increasing in percentage of HDPE in the mixture of (PMMA-HDPE) reduces electrostatic charge generated from friction.
3. There are strong dependency of fabric type on the generated (ESC).

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