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Friction Characteristics of Aluminized Polyester Fabric under Dry - and Water- Lubricated Conditions

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Abstract – Materials made from plastics are increasingly utilized in constructing greenhouses and setting up shield structures. Polyester fabrics have a wide range of use in horticulture and other fields of agriculture. They are utilized as a greenhouse cover and also help in combating intense climate variation in the field. Over time, these fabrics may experience friction against other surfaces. Owing to this, the surface framework of the material degenerates. This study examines the frictional characteristics of aluminized polyester fabric in both dry- and water-lubricated environments under changing applied loads and sliding speeds. Friction experiments are performed at room temperature by employing a pin on a disk. The experiments reveal that the friction coefficient decreases with increase in applied load in both dry sliding and water-lubricated environment. However, the friction coefficient decreases more under the water-lubricated setting than in the dry state. At the maximum applied load, the highest friction coefficient is discovered in the dry state with a range of 0.282 to 0.237, whereas a friction coefficient of 0.229 to 0.189 is observed in the water-lubricated state. Additionally, it is observed that the friction coefficient increases with an increase in sliding speed under both experimental environments. The examination of specimen surfaces reveals that the abrasion is minor in the water-lubricated setting compared with that in the dry state.

Keywords – abrasion, aluminum, friction coefficient, greenhouse, polyester

1. Introduction

Greenhouse farming is regarded as the best method of producing crops as it yields an output per farmed unit field as many as ten-folds compared to crops cultivated in an open field [1]. Fruit crops as well as vegetables are farmed globally under greenhouse environ-ment. The covering materials employed in greenhouse provides regulated microclimates, which are suitable to crop condition and as a result, improved quality and output are achieved. The application of polymeric com-posites on greenhouses as cover material is expanding worldwide due to the fact that it can enhance fruit quality and output by shielding plants from severe weather modifications, providing optimal growth environ-ment, prolonging the development period and mitigating plant morbidities [2]. Polyester is a synthetic fibre obtained from oil and the most frequently utilized filament. It is light, robust as well as readily dyed. It can be knitted or woven and also effortlessly mixed with different materials. Polyester surpassed cotton application in the early 2000s and, the alternative synthetic fibre constitutes over half of fabric

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employed within the textile industry [3].

In recent times, aluminium has proven to be useful for thermal curtains in greenhouses because it enhances insulation as well as protection from the light. Aluminized covers preserve approximately one-tenth additional energy compared with non-aluminized ones. Aluminized covers are developed to throw the infrared radiation discharged by greenhouse framework back into the greenhouse and also reflect heat away from the greenhouse [4]. Synthetic polymers perform significant roles in agricultural practices as structural fabrics for establishing a climate profitable to plant development seen in greenhouses, mulches etc. Nevertheless, among the main desired qualities for the application of polymers for such uses are their physical characteristics like stability and weather resistance [5]. Polymeric materials are exposed to extensive abrasion-related conditions such as in the greenhouse construction, where supporting structures are made of steel. The demand for polymers for such use is on the basis of their low friction coefficient, elevated specific strength, good wear properties as well as economic viability. Abrasion is known as the physical ruining of fibres, fabrics and yarns generated through the rubbing of a textile surface with some other surfaces [6].

Textile supplies might be ineffective due to various elements among which abrasion is one of them. Abrasion takes place through wearing or washing operation and this can deform the fabric and induce fibres to be removed from the surface. Abrasion gives rise to the failure of efficiency features like strength and thus influences the fabric presentation [7]. The friction, along with the wear properties of polymers and composite materials gliding over irregular steel counter face were studied by Nuruzzaman et al [8]. Results indicated that the frictional amounts of these polymers along with their composites are considerably affected by the load used as well as the rubbing length [9]. Furthermore, wear amount of these polymers along with their composite materials are greatly affected by the used loads. The effect of sliding speed on the rubbing and wear of these elements over irregular steel counter face was also studied. The result demonstrated that coefficient of friction elevates with higher sliding speed for each of the materials examined. In addition, it was discovered that wear amount of these polymers and composite materials are greatly affected by sliding speed. Following friction operation, it was noted that surface roughness of these elements are considerably altered subject to sliding speed [10].

A number of researchers recorded that friction along polymers rubbing over metal rely on a number of parameters such as surface roughness, normal load, sliding speed, humidity, lubrication and many more. Among these variables, sliding speed and applied load are the dominant influential variables that determine the tribological characteristics of the material. The coefficient of friction of polymers along with their composites sliding over metal decreases or increases according to the extent of the working environment as well as sliding couples [11]. Regardless of the above mentioned scholarly researches, there are no particular investi-gations reported, so far, on the frictional characteristics of aluminized polyester fabric as a function of sliding speeds and normal load in dry and water lubricated environments. From the operational perspective, such features are extremely important as the material is vulnerable to diverse loads, sliding rates and adverse environmental conditions when utilized in the field.

2. Experimental Detail

2-1. Materials

In this experiment, aluminized polyester fabric specimens were employed as the examination material. It was utilized as the insulation cover in a horticultural greenhouse. figure 1 show the behaviour between textile and metal. Consequently, friction characteristics of aluminized polyester fabric in both dry and water lubricated environment are essential elements in this field. In this regard, this investigation was aimed at investigating friction qualities of the specimen. Furthermore, images of surfaces before and after friction tests of the specimens employed were captured using a SNE-4500M scanning electron microscope which was

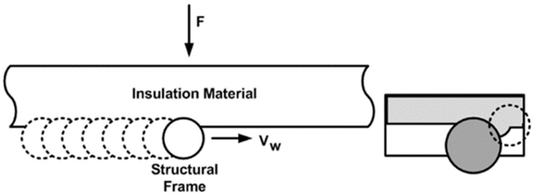


Fig. 1. Behaviour between textile and metal materials.

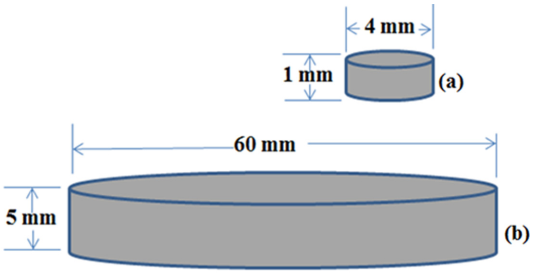


Fig. 2. Diagrams of (a) pin and (b) disk.

linked to a computer and studied. The device was operated at accelerating voltage of 10 kV and magnification levels of ×28, ×200 and ×400. The cylindrical pin and disk used in this study were composed of steel. The pin had a diameter of 4 millimetres and thickness of 1 millimetre, whereas the disk was 5 millimetres thick and 60 millimetres in diameter as demonstrated in figure 2. Their surfaces were finished by eliminating the burr to maintain uniformity. Cylindrical steels were processed into dimensions in accordance with American Society for Testing and Materials (ASTM) standard. Both pin and disk were ultrasonically washed using acetone for 10 minutes to eliminate dirt and oil on their surfaces. The aluminized polyester fabric sample was cut into the disk diameter and covered on the disk surface.

2-2. Tests Conditions

In this study, friction characteristics were evaluated by the use of a pin-on-disk tribotester as shown in figure 3. The pin-on-disk tribotester was operated according to ASTM G99 standard for the aluminized polyester fabric to achieve the influence of the applied load and sliding speed in dry and water lubricated operating environment. The entire measurements were carried out on two examination samples under individual conditions of dry and water sliding ,and the average readings were utilized to create effect curves. The pin-on-disk instrument consisted of a flat pin which was connected to a firm elastic arm that was weighted down onto a test specimen with an accurately measured weight. The specimen was rotated at a chosen speed. The elastic arm guaranteed an approximately fixed contact spot and a steady position in the friction track created by the pin on the specimen. The kinetic friction coefficient was ascertained during the experiment through direct evaluation of the changes in torque using a sensor situated at the pivot position of the arm. The com-ponents of the test machine included a pin sliding over the flat face of a disc covered with aluminized polyester fabric turning in a vertical plane as shown in Figure 4, with provisions to control the speed and load. The load was applied along the axis of the pin. The examination was carried out by varying the load from 2 N to 4 N, 6 N, 8 N, and10 N with different sliding speeds of 0.06 m/s, 0.10 m/s, 0.14 m/s, 0.18 m/s, 0.22 m/s, 0.26 m/s, 0.30 m/s, and 0.34 m/s. The detailed experiment con-ditions are depicted in Table 1.

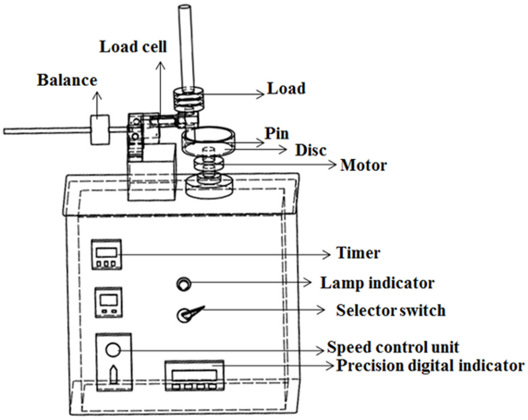


Fig. 3. Drawings of pin-on-disk device.

2-3. Friction Analysis

Figure 5 demonstrates the path of forces during the friction analysis. Load (W) is used over the pin while the disk turns at a fixed angular speed (ω). The turning results in friction amid two interacting surfaces. The load applied over the pin surface had particular range, defined as ‘r’ away from the middle of the disk. As

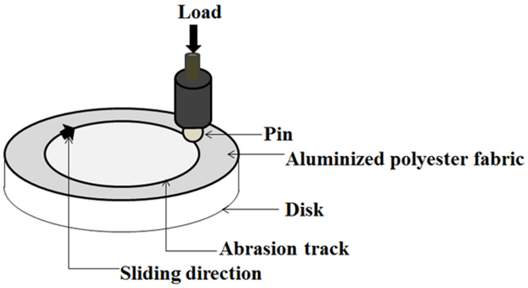


Fig. 4. Pin sliding on disk covered with aluminized polyester fabric.

Table 1. Conditions of friction analysis

Parameters	Settings
Type of Contact	Pin-on-disk
Disk	steel
Pin	steel
Specimen	Aluminized polyester fabric
Surface roughness Disc (μm)	0.05 Ra
Surface roughness Pin (μm)	0.05 Ra
Range of normal load (N)	2, 4, 6, 8, 10
Sliding speeds (m/s)	0.06~0.34
Temperature (°C)	Room temperature (25°C ± 0.2°C)
Environment	Dry and water lubricated

shown in figure 5, the torsion over the disk is noted as F_{app} and the rate of F_{app} is equal to F_t. Static friction force F_c operates in the reverse path. The difference between F_t and F_c is the net force F_{Net}. The net force F_{Net} and tangential force F_{tf} depict the force of dynamic friction. The net force is equal to the tangential force [12].

$$F_t = F_{app} \tag{1}$$

$$F_c = \mu_S W \tag{2}$$

$$F_t - F_C = F_{Net} \tag{3}$$

$$F_{Net} = \mu_d W \tag{4}$$

$$F_{Net} = F_{tf} \tag{5}$$

$$\mu = \frac{F_{tf}}{W} \tag{6}$$

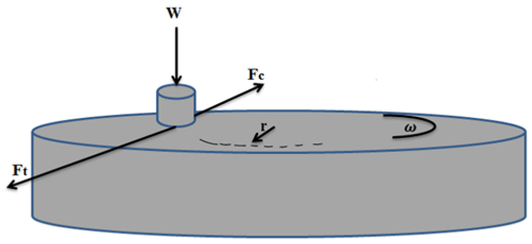


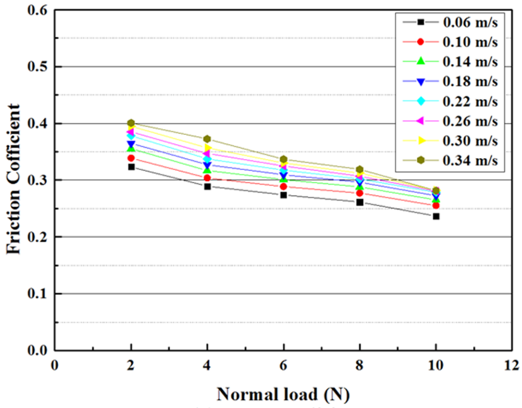
Fig. 5. Forces operating in the pin-on-disk test.

3. Results and Discussion

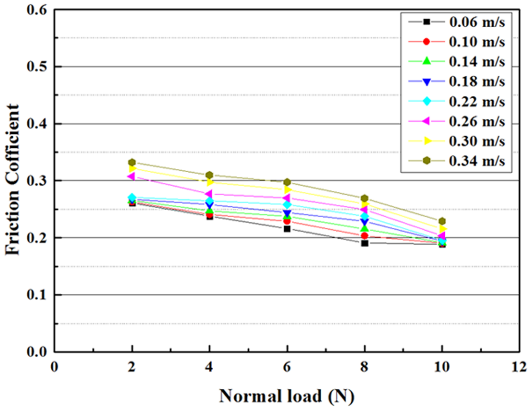
3-1. Influence of normal load and sliding speed on friction coefficient

Figure 6 (a-b) demonstrate the changes in friction coefficient with implemented load under dry and water lubricated sliding environments respectively. According to the figure 6(a-b), an increment in normal load led to reduction in the mean friction coefficient under both dry and water lubricated states. Exercised force, covering material, and fabric orientation are variables that influenced friction as well as abrasion action. When the load on the fabric sample was elevated, it gave rise to compression as well as relatively flattening of the surface, consequently, decreasing the friction coefficient.

Furthermore, from the Figure 7 (a-b), it is noted that

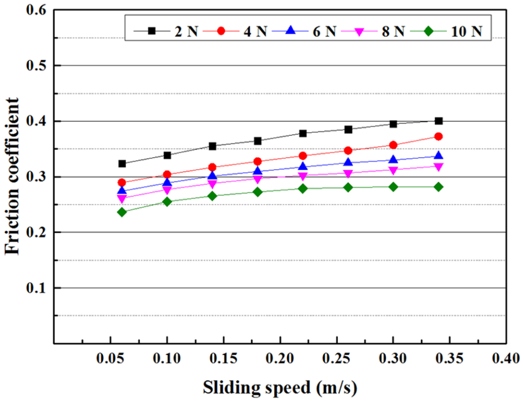


(a) Dry condition

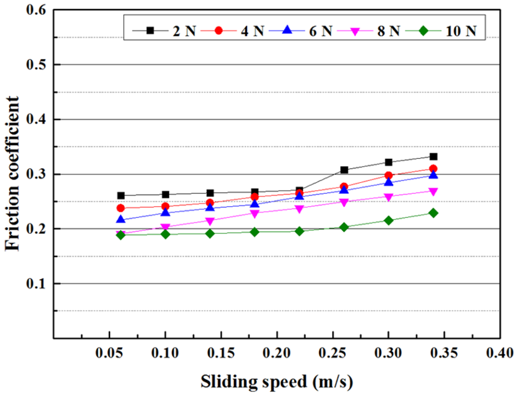


(b) Water lubricated condition

Fig. 6. (a-b) Changes in friction coefficient with implemented load under dry and water lubricated sliding environment.



(a) Dry condition



(b) Water lubricated condition

Fig. 7. (a-b) Changes in friction coefficient with sliding speed under dry and water lubricated sliding environment.

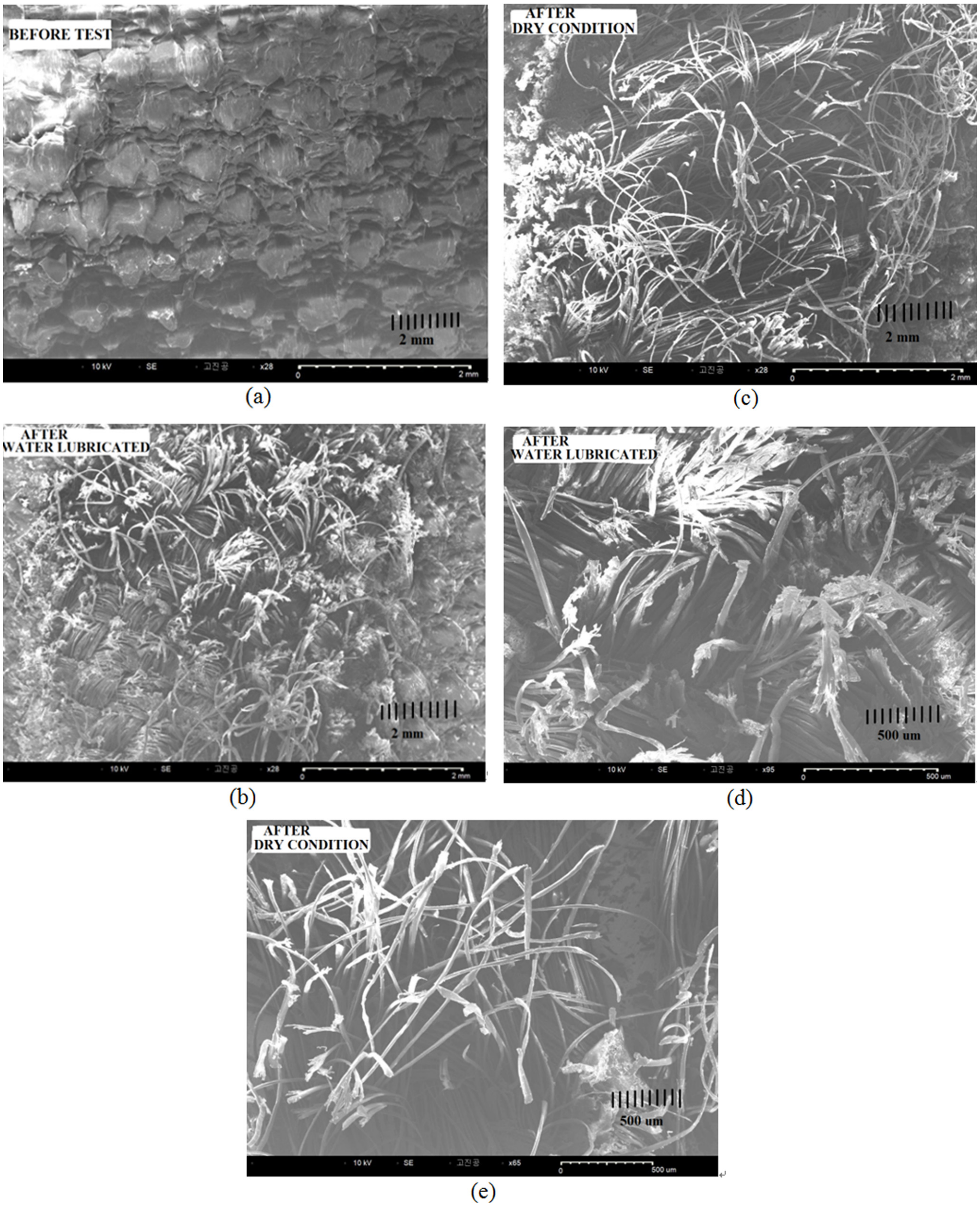
the friction coefficient was elevated with further sliding speed in dry state as well as in water lubricated environment. Under the entire experiment environment, the highest friction coefficient was discovered in dry sliding state ranging from 0.282 to 0.237, compared with 0.229 to 0.189 obtained in the water lubricated environment. The dissimilarity in friction coefficient levels amid dry sliding and water lubricated conditions may be interpreted as temperature rise of the steel surface due to frictional power. This gives rise to loosening of polymer atomic chains and also causes the bond to get feeble. As a result, strands are shattered into shreds and produce debris. Typically, the friction coefficient observed in water lubricated sliding environments is lower than that of dry states. This fall in friction coefficient is as a result of the role which water performs as lubricant. The produced debris is washed away from the contact of steel pin and specimen due to the presence of water.

3-2. Scanning Electron Microscopy (SEM)

Distinctive SEM characteristics of shabby surfaces of aluminized polyester fabrics at different used load of 2 N to 10 N along with sliding speeds of 0.06 m/s to 0.34 m/s in both dry and water lubricated environments are displayed in figure 8 (a-e). Figure 8(a) shows the surface characteristic of aluminized polyester fabric before the tests. SEM image displayed in figure 8(b) shows the features of shabby surface of aluminized polyester specimen under water lubricated sliding environment. It shows the minor extent of abrasion in the presence of water acting as lubricant and coolant. Figure 8(c) shows the SEM features of aluminized polyester specimen in dry gliding environment. It is noted that fibre rupture and exposure were greater in dry sliding setting than in water lubricated environment. These surface observations demonstrate that abrasion of the examined material is less in water lubricated states compared to dry conditions.

4. Conclusions

Friction analyses were performed on aluminized polyester fabric to ascertain its frictional characteristics in both dry and water lubricated sliding environments. From the experiments, the following conclusions may be taken; as the implemented load increases, friction coefficient shows a decreasing tendency in both sliding environments. However, the level of friction would be lower in water lubricated setting than in dry state. It is noted that, when the pressure on the fabric specimen rose, it led to flattening of fabric surface, and as a result lowers friction coefficient. It was also discovered that the higher friction coefficient was demonstrated in the dry sliding setting while lower value existed in the water lubricated setting. Furthermore, it is observed that with an increase in the sliding speed, friction coefficient elevates in both dry and water lubricated sliding setting. Following the friction operations, the microstructures of abraded specimen surfaces under the entire environments revealed extreme abrasion in dry state more than in water lubricated setting.



(a) (c) (b) (d) (e)

Fig. 8. (a-e) SEM images of aluminized polyester fabric before and after tests at varied loads and sliding speeds under dry and water lubricated settings.

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