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INVESTIGATION OF FRICTION COEFFICIENT OF THE SURFCAE OF ROBOTIC GRIPPER

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ABSTRACT
Safe handling of products in production lines is an industrial application vastly needed for grippers. To ensure that, it is essential to determine the friction coefficient. In the present work, friction coefficient of the gripper surface is investigated. Rubber specimens of different hardness and roughness were tested as surface coating of the gripper. The tested rubber slid against the surface of polyester textiles.

Experiments revealed that the friction coefficient decreased as the load increased. Increasing surface hardness of the rubber caused significant increase in friction coefficient. It was found that friction coefficient depends on the type of the textile specimens. Finally, friction coefficient significantly increases up to maximum then slightly decreases with increasing surface roughness. This observation recommends more investigations to select properly the rubber materials for coating gripper.

KEYWORDS
Robot, gripper, rubber, friction coefficient, textiles.

INTRODUCTION
Pick and place is critical part in automated manufacturing process. It is necessary to grip objects easily, [1, 2]. Grasping and placing of objects are the main function for robotic manipulators. Surface of the gripper plays main role in grasping objects. Safe grasping avoids the slip of the objects during picking and placing. The structure of gripper was developed to decrease the contact forces and makes were decreased to increase the large objects grasping capability, [3]. It was suggested a gripper made from rubber material to suck and grasp different types of objects, [4]. In best gripping process, it was necessary to decrease the grasping force to avoid deformation of the objects, [5]. It was recommended to design gripper of increased stiffness to grasp a large variety of objects, [6]. Besides, it was aimed to grip the object with minimum energy, [7]. The experiments showed that, when materials became softer, there were a very high grasp of objects according to the friction results between different objects and when the dynamic of friction coefficient became lower, the results of roughness showed higher trend, [8]. The suggested flexible universal gripper is an inexpensive and comprehensive solution to handle objects of

variable shape. The gripper design is developed to include features such as manufacturability, safety, light-weight, effective gripping, economy and stable holding of items, [9]. Rubber as a soft material during interacting with the surface of hard material mechanically shows high pronounced microscopic deformations. Rubber shows greater friction coefficients than plastic. The factories affecting friction coefficient measurement include the material and surface geometry of the objects and gripper, [10]. It was recommended that friction coefficient increased with increasing the cotton content in textile, where polyamide specimens showed the lowest friction, [11]. The synthetic textiles showed relatively lower friction coefficient than synthetic leather during sliding against polyester clothes at dry condition. Although, synthetic leather showed relatively lower friction than synthetic textiles when sliding against cotton clothes. Friction coefficient a bit decreased with increasing load. At dry sliding, wool clothes recorded the highest friction values among the tested clothes, [12, 13].

In the present work, it is aimed to determine the proper hardness and surface roughness of rubber specimens used as a gripper coating material by sliding against textiles to determine their friction coefficient at dry sliding condition.

EXPERIMENTAL

Friction test rig was used in the present work to measure the friction force displayed by the sliding of the tested rubber specimens against the different types of textiles. The textile specimens are placed on a base supported with two load cells, the first measures the vertical force (normal load) and the second measures the horizontal force (friction force), Figs. 1, 2. A digital screen was attached to the load cells to reveal the vertical and friction forces. The friction coefficient is determined by taking ratio between the friction force and the normal load.

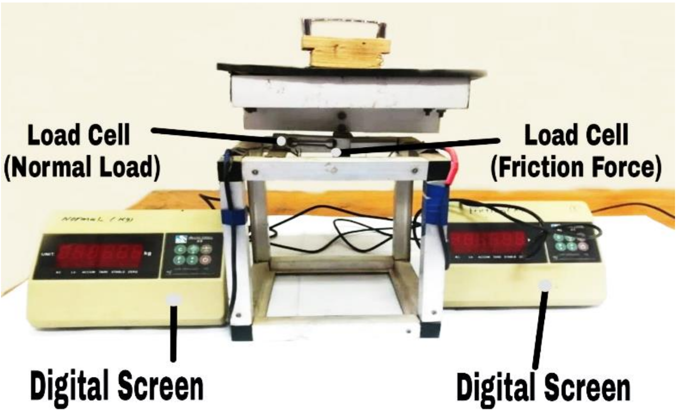


Fig. 1 The arrangement of the test rig.

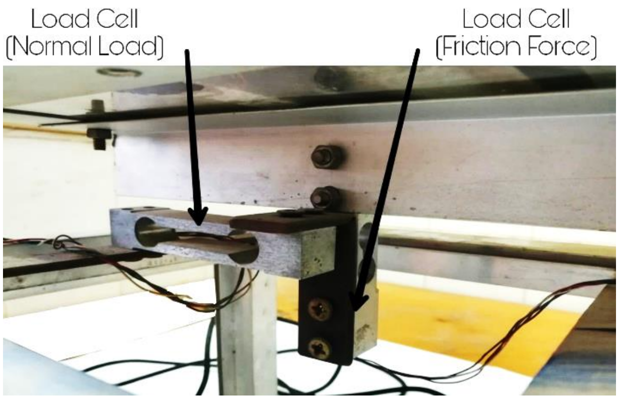


Fig. 2 Horizontal and vertical load cells of the test rig.

In the present work, rubber specimens were in the form of square of 40 × 40 mm^2 and 5 mm thickness of different hardness measured in Shore (A). The normal loads were 1.6, 1.8, 2.0, 2.5 and 3.5 N. Rubber slid against different types of polyester textiles, Table 1. The hardness of rubber specimens was ranging from 5.3 to 11.2 Shore A, Table 2.

Table 1 The tested textiles.

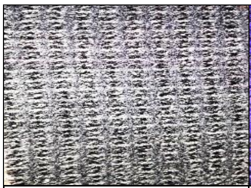
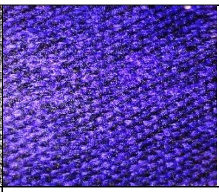
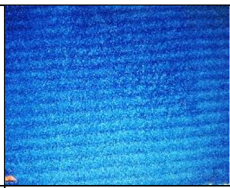
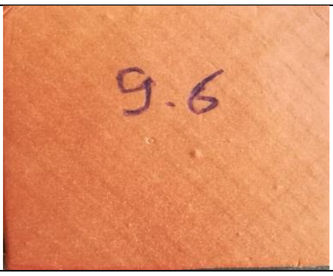
				
AA	**BB**	**CC**	**DD**	**EE**

Table 2 The tested rubber.

		
A. (11.2 Shore A)	**B. (9.7 Shore A)**	**C. (9.6 Shore A)**
		
D. (9.1 Shore A)	**E. (8.8 Shore A)**	**F. (8.3 Shore A)**
		
G. (7.1 Shore A)	**H. (7.00 Shore A)**	**I. (6.9 Shore A)**
		
J. (6.6 Shore A)	**K. (5.8 Shore A)**	**L. (5.3 Shore A)**

Rubber test specimens were adhered to a wooden block representing the gripper coating material and slid against different types of textile under different normal loads. The tested surfaces were cleaned from contaminants and well dried before the test. The method of determining friction coefficient is illustrated in Fig. 3.

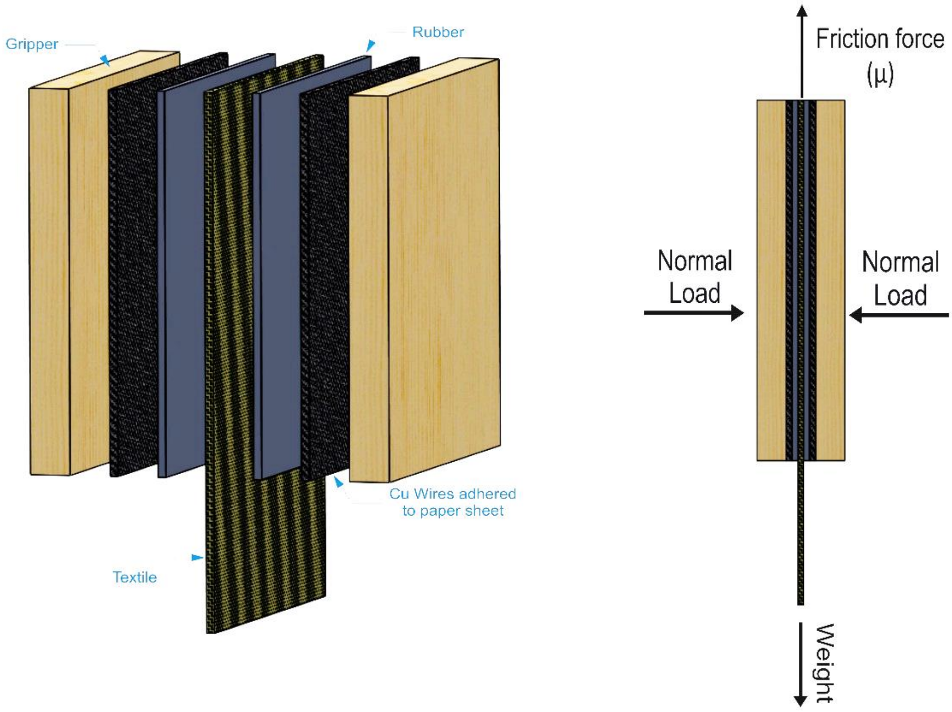


Fig. 3 Friction coefficient between gripper and textile.

RESULTS AND DISCUSSION

The effect of applied load on friction coefficient displayed by sliding of rubber of different hardness on Textile AA is shown in Fig. 4. It is illustrated that as teh load increased friction coefficient decreased. It seems that the applied load was too high that the rubber was loaded in the plastic condition, where shear strength decreased. When rubber slides on a surface, the rubber molecules bind to the surface and elongate until the bond between the molecule and the substrate is broken. Then the molecule tries to rebind to the surface again. During this process, the shear stress acting in the contact area control the friction value. Based on that observation, 3.5 N was the value of the load considered for the results in Figs. 5 – 14. The decrease in the friction values with increasing normal load is attributed to due to saturation of the rubber asperities and rubber filling the gaps between the track asperities, where the rubber in the contact area deformed in such a manner as to completely follow the short-wavelength surface roughness profile of the counterface.

The results of experiments carried out to measure friction coefficient displayed by sliding of rubber as coating material for gripper against the textile specimens as gripped object are shown in Figs. 5 - 14. The aim of the experiments was to investigate the effect of the hardness of the friction coefficient. Significant increase in friction coefficient with increasing the hardness is observed for the sliding of rubber of different hardness against two textile (AA), Fig 5. The rubber of the lowest hardness (5.3 Shore A) displayed the lowest value of friction (0.43), while rubber specimen of relatively higher hardness (9.7 Shore A) showed relatively higher friction (0.55). The same trend was observed for the

textile specimens BB, CC, DD and EE, Figs. 6 – 9 respectively. The values of friction coefficient varied according to the type of textile specimens. The lowest friction value (0.42) was recorded for sliding of rubber of 5.3 Shore A hardness on textiles CC and EE, while the highest value (0.62) was determined for sliding rubber of 9.7 Shore A hardness on textile EE. Knowing that the load was 3.5 N. Based on the results, it can be concluded that friction coefficient depends on both of the hardness of rubber and properties of the surface of the textile. The values of surface roughness of the tested rubber specimens were ranging between 9.8 and 12.9 μm R_a.

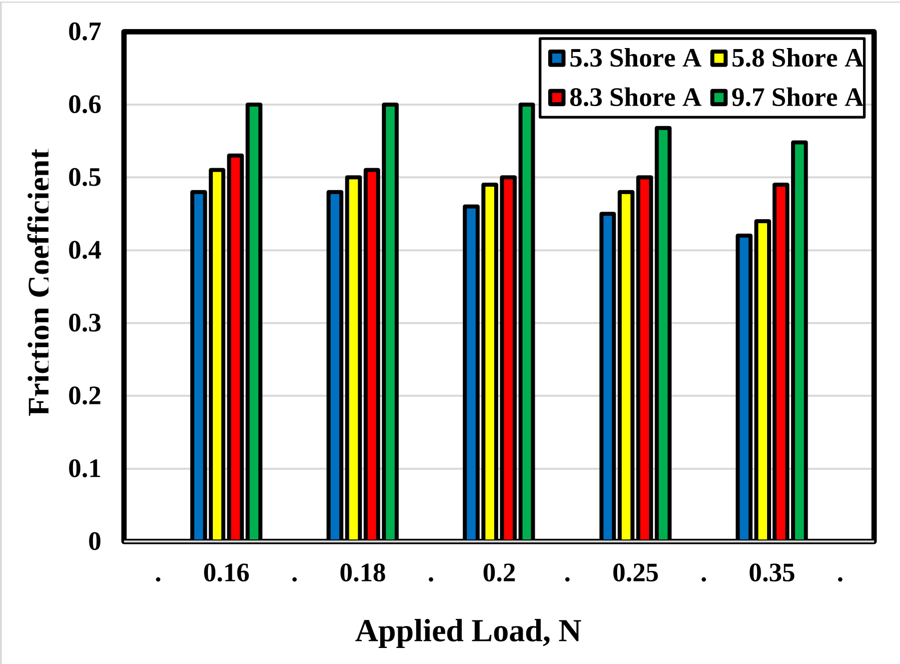


Fig. 4 Effect of applied load on friction coefficient displayed by sliding of rubber of different hardness on Textile AA.

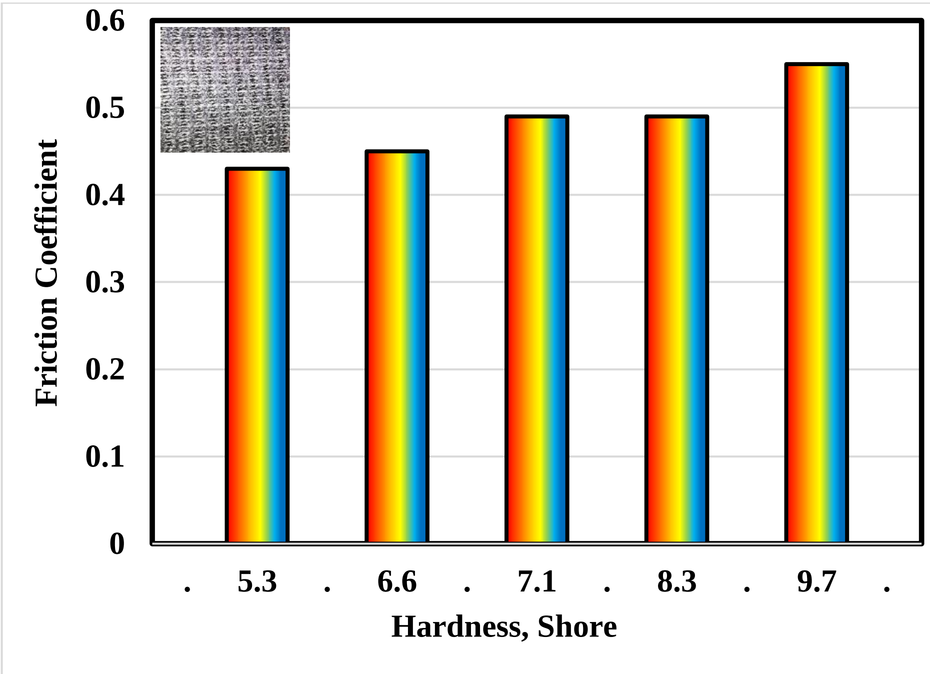


Fig. 5 Friction coefficient displayed by Textile AA.

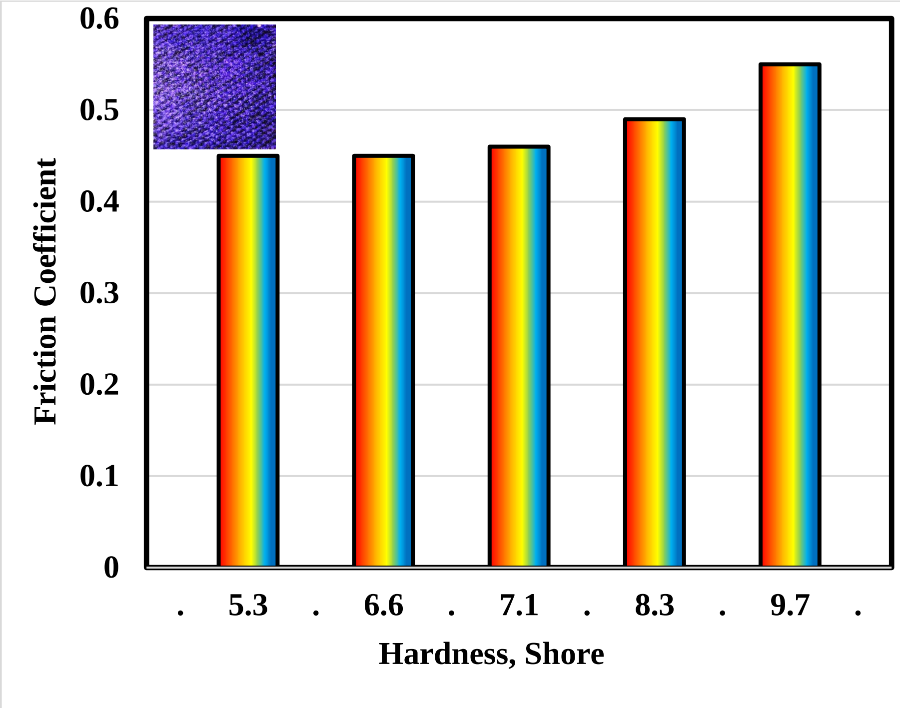


Fig. 6 Friction coefficient displayed by Textile BB.

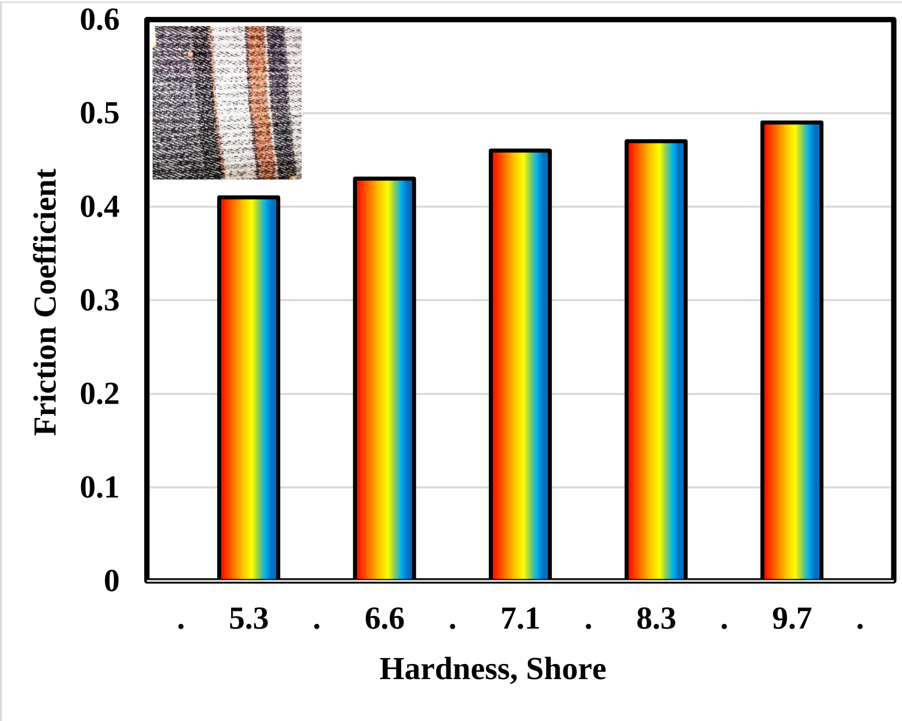


Fig. 7 Friction coefficient displayed by Textile CC.

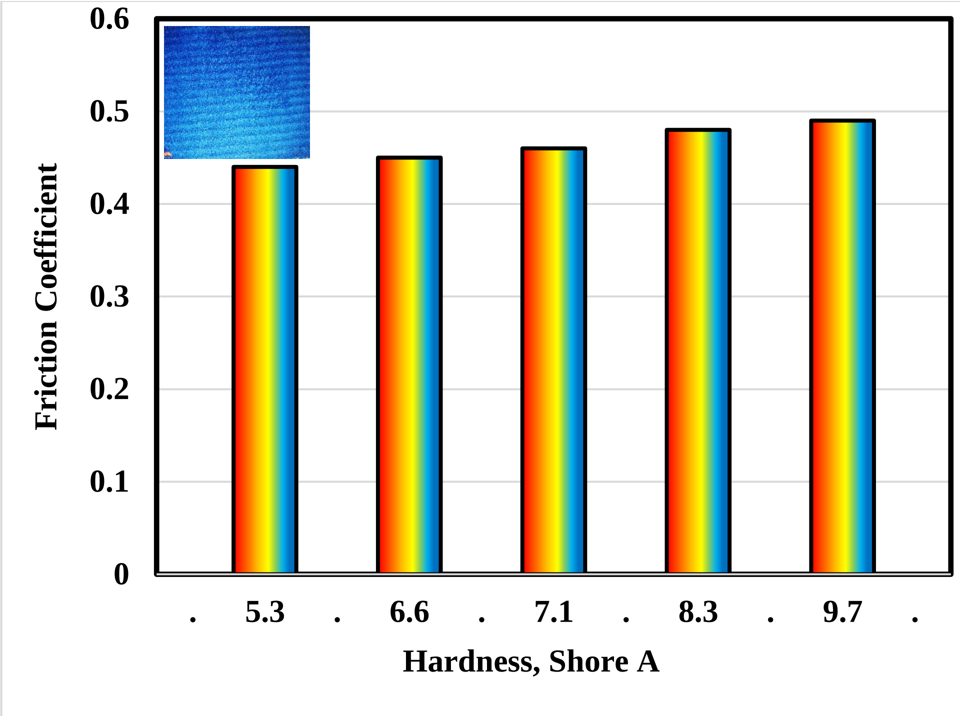


Fig. 8 Friction coefficient displayed by Textile DD.

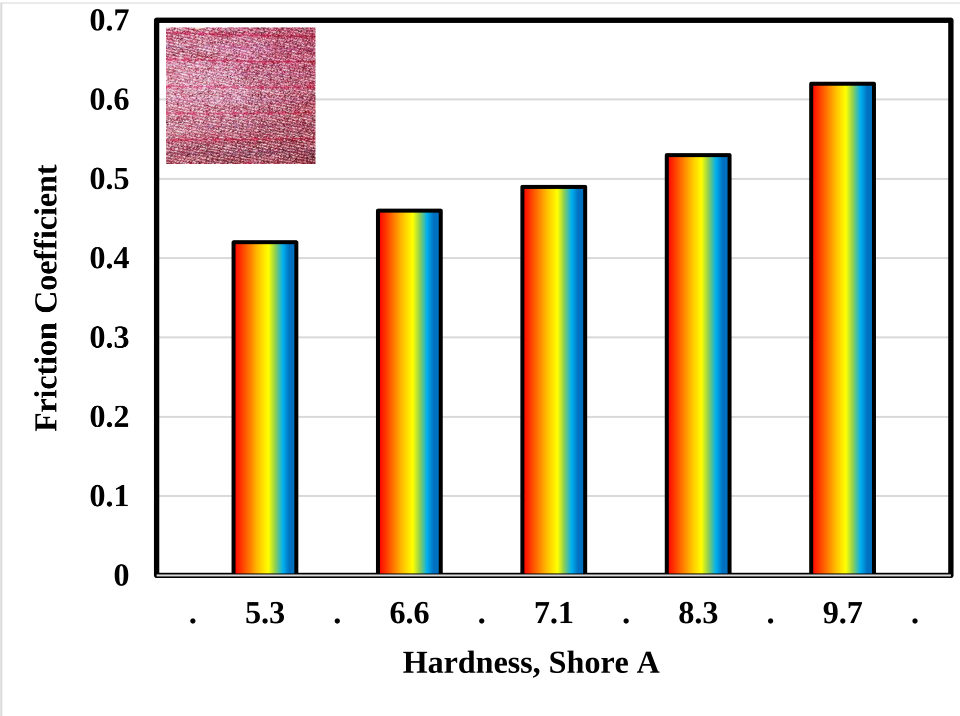


Fig. 9 Friction coefficient displayed by Textile EE.

Friction of rubber against surfaces depends on the attractive binding force generated between the rubber surface and the surface. The adhesive contribution results from the attractive binding forces between the rubber surface and the substrate. When the rubber surface is smooth, the attraction becomes stronger and increases the contact area. Consequently, the friction force increases due to the low elastic modulus of rubber allowing high value of contact area. Adhesive factor of rubber friction will be lower

because of the small contact area for rough surfaces. The frictional shear stress of rubber controls the values of friction coefficient.

At dry sliding, rubber friction consists of adhesion and hysteresis [14 –17]. Hysteretic friction results from the rubber is being subjected to cyclic deformation by the surface roughness of the rough counterface. The surface asperities of the rubber exert oscillating forces on the counterface causing energy dissipation through the internal friction of the rubber. Adhesion and deformation components of friction are due to the viscoelastic properties of the rubber. The relationship between friction coefficient and surface roughness can be divided into two stages. The first one shows relatively high friction for the relatively smooth tested rubber specimens, where they displayed relatively higher friction due to the adhesion since the contact area represented higher value. As the roughness increases the stick-slip process introduced on a molecular level increases and consequently increases adhesion and friction coefficient. The second stage of friction, where its value slightly decreased with increasing surface roughness, can be discussed on the basis that, as the surface roughness increased the area of contact decreased. In this condition, adhesion between the sliding surfaces decreased causing significant decrease in friction coefficient.

Further experiments were carried out to investigate the influence of the surface roughness of the rubber surface on friction coefficient, where the surface roughness ranged between 6 – 23.3 µm. The results revealed that friction coefficient significantly increased up to maximum then slightly decreased with increasing surface roughness, Figs. 10 – 14. The friction increase can be explained on the bases that it is known that smoother surface in general have relatively lower friction values compared to rougher surface. It seems that rough asperities of rubber surface increase the friction force by their rubbing the counterface under relatively higher contact stress.

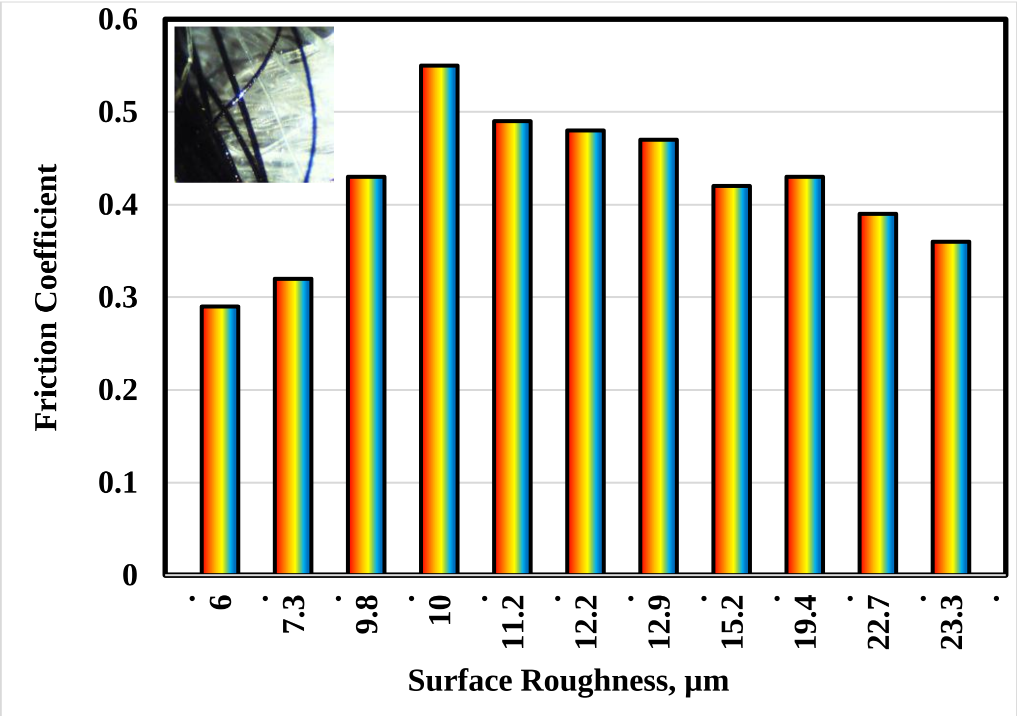


Fig. 10 Friction coefficient versus surface roughness of rubber for Textile AA.

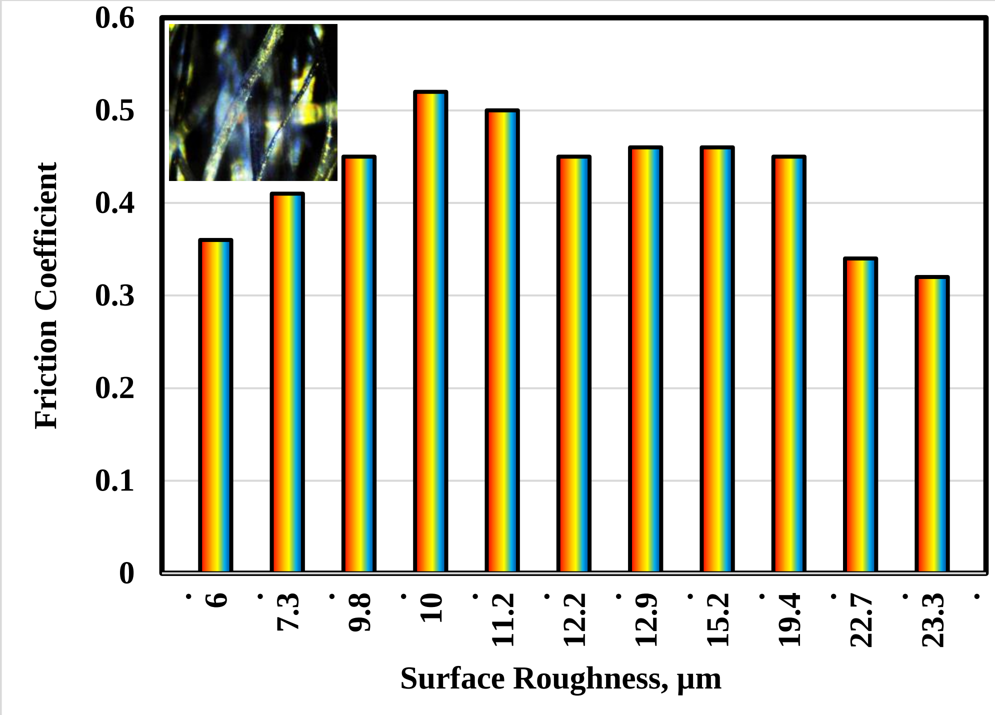


Fig. 11 Friction coefficient versus surface roughness of rubber for Textile BB.

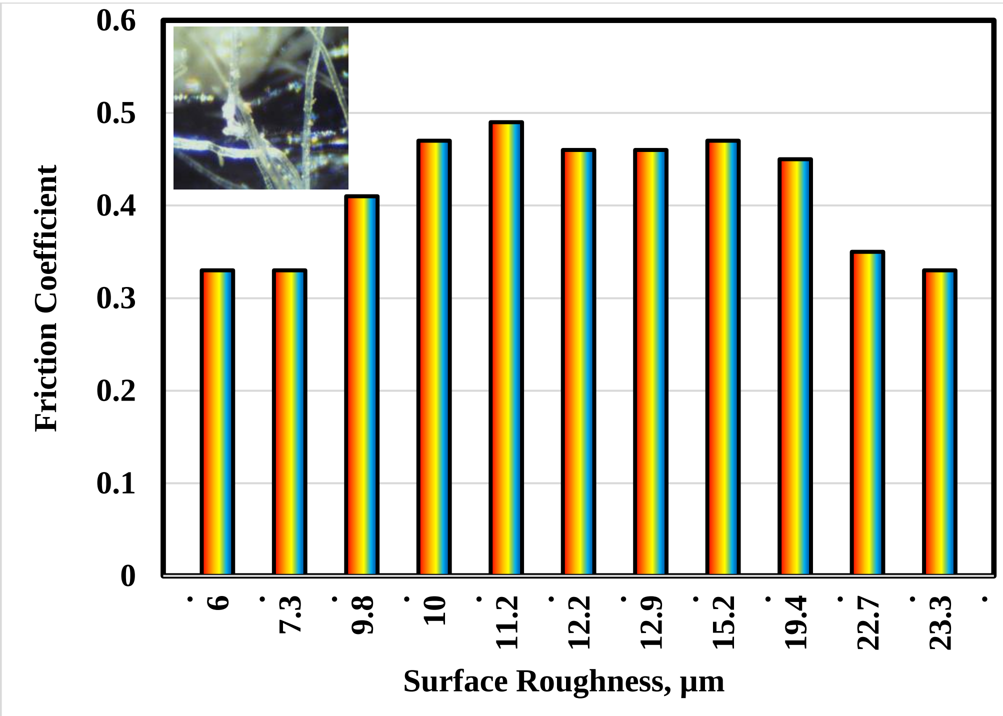


Fig. 12 Friction coefficient versus surface roughness of rubber for Textile CC.

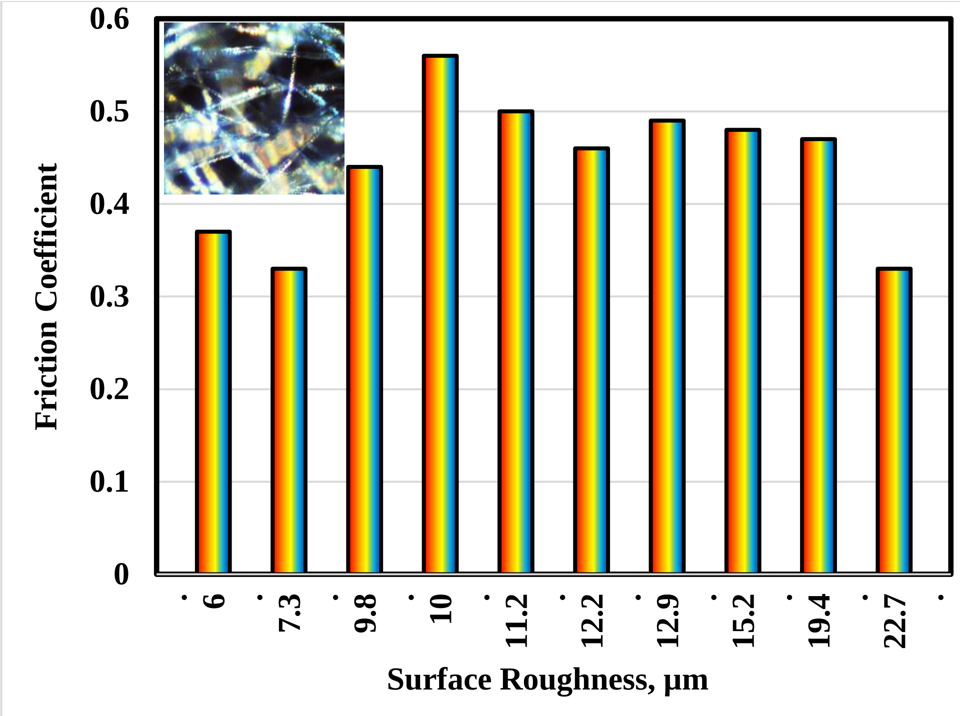


Fig. 13 Friction coefficient versus surface roughness of rubber for Textile DD.

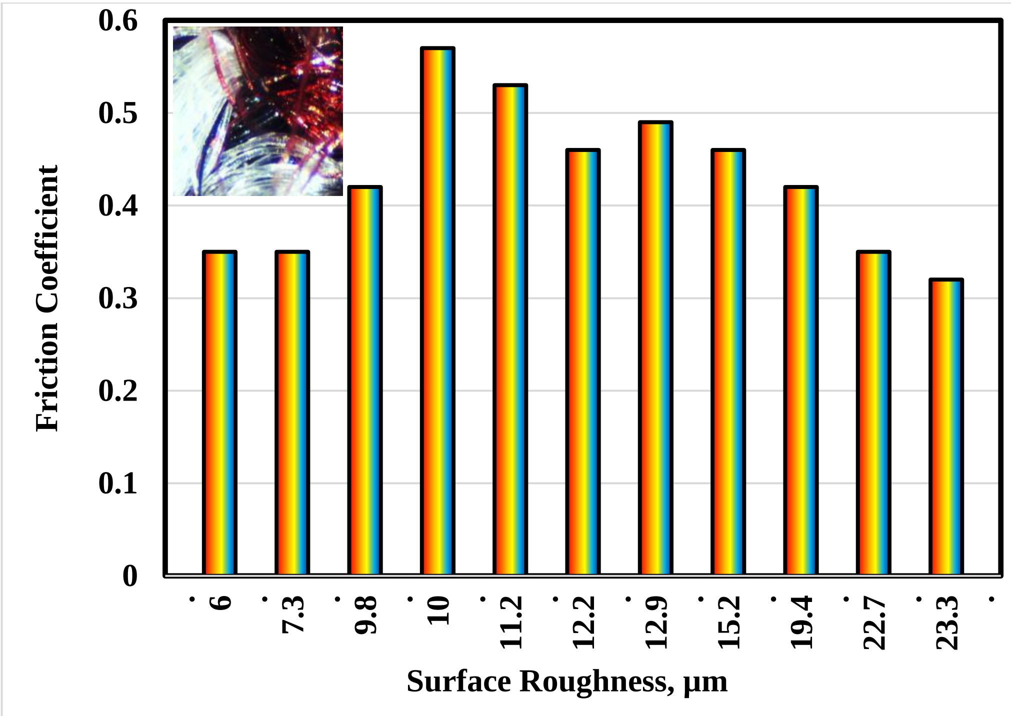


Fig. 14 Friction coefficient versus surface roughness of rubber for Textile EE.

CONCLUSIONS

1. As the load increased friction coefficient decreased.

2. Significant increase in friction coefficient was observed with increasing the surface hardness of the tested rubber.

3. The friction coefficient depends on the type of the textile specimens.

4. Friction coefficient significantly increases up to maximum then slightly decreases with increasing surface roughness.

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