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WEAR RESISTANCE OF STEEL COATED BY POLYURETHANE REINFORCED BY STEEL WIRES

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ABSTRACT
Sand erosion of steel sheets coated by polyurethane and reinforced by steel wires of different diameters is discussed. The tested polyurethane composite coatings are proposed to defeat sand erosion during dusty storms. Experiments have been carried out using sand blast test rig.

Based on the experimental results, it was found that wear of polyurethane coatings reinforced by steel wires decreased drastically with increasing wire diameter due to the strengthening effect of the steel wires. When the distance between the wires decreased, wear decreased. As the polyurethane coating thickness increased, wear increased. Besides, wear of polyurethane reinforced by gridded steel wires decreased with increasing wire diameter. At lower values of wire diameter, wear recorded relatively lower values than that displayed by longitudinal wires. It seems that gridded wire reinforcement strengthened the coating and increased the bonding force between polyurethane and steel wires.

KEYWORDS
Erosion, sand, steel sheets, polyurethane coating, wear, steel wires.

INTRODUCTION

Polyurethane coatings reinforced by copper wires are proposed to defeat erosion wear of surfaces such buildings and tanks by sand during dusty storms. Experiments have been carried out using sand blast test rig. Based on the experimental results, it was found that erosion wear decreases with increasing wire diameter, where the wire strengthens the eroded area. Besides, minimum value of wear of polyurethane coating reinforced by copper wires is observed when the substrate was coated by two layers, [1]. The solid particle erosion of epoxy glass fibre composites (Epoxy/GF) is investigated by sand blasting equipment, [2]. The impact angles (30°, 60°, and 90°), distance from the sand jet and oil content (2.5, 5, 7.5, 10) filling epoxy matrix are studied. The results show a strong dependency of oil content on the material behaviour form brittle to ductile. The morphology of eroded surface is observed under microscope and damage mechanisms are discussed. The sand erosion testing, of transparent polymeric coatings of steel sheets, was investigated, [3]. The tested coatings were aimed to coat the vehicle surfaces as well as lamp covers to defeat sand erosion during dusty storms. An air-sand erosion test rig was designed and manufactured for that purpose. Four types of transparent polymeric

coatings were tested. Based on the experimental results, it is found that the lowest wear values were observed for coating thickness of 0.08 mm. At 90° angle of inclination, embedment of sand particle was indicated by the weight increase after test. Heat treatment of the coatings caused significant wear decrease. Wear decreased down to minimum then remarkably increased with increasing angle of inclination.

Solid particle erosion is a general term used to describe the mechanical degradation (wear) of any material subjected to a stream of erodent particles impinging on its surface. The effect of particle erosion on structural and engineering components has been recognized for a long time, [4]. The aim of solid particle impact testing is to investigate the resistance to erosion by solid particle impact of materials with a wide range of mechanical properties, and to explore the correlation between erosion rate and mechanical properties. An aircraft is most likely to encounter dust and sand during take-off and landing, and rain during ascent and descent, as cruising altitudes are generally above cloud levels, [5]. However, military aircraft and missiles may experience all types of conditions.

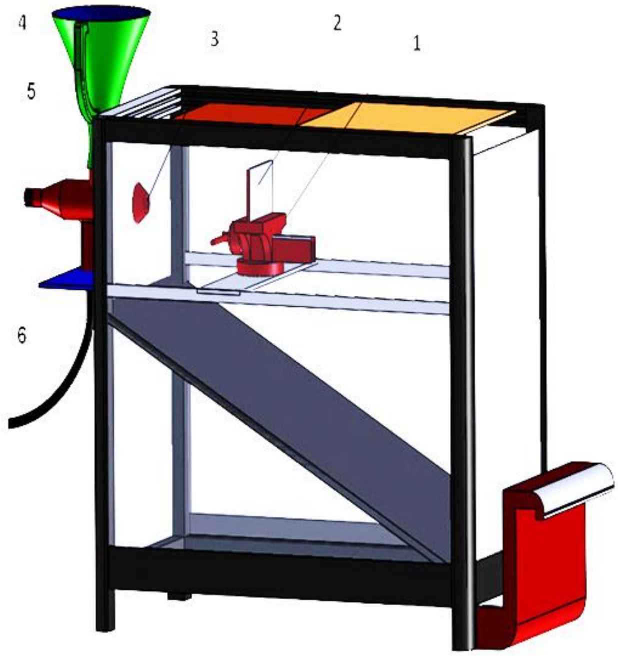
Erosion of polymers and polymer matrix composites includes two modes: brittle and ductile erosion depending on the variation in the erosion rate (ER) with impact angle. If ER goes through a maximum at 15° – 30° impact angles, the response of the eroding material is considered ductile. In contrast, if ER continuously has a maximum at 90° (normal impact), the eroding material is considered as brittle, [6]. Polyethylene (PE) was eroded by sand particles. Most erosion was found to occur at an angle of 20–30°, while the weight loss became zero at around 80°. Transitions in the wear response of the target materials have been related into changes in the erodent characteristics, like shape, hardness or size of the sand particles [7 - 9]. The operating environment in Middle East is particularly severe in terms of the high ambient dust concentrations experienced throughout the Eastern and Western Provinces, [10]. During severe dust storm conditions dust concentrations of the order of 100 to 500 times higher may be encountered. It was found that the vast majority of airborne in the Eastern Province are concentrated in the smaller sizes. 95 % of all particles are below 20 µm and 50 % of all particles are below 1.5 µm in size. The dusty storms continue for long times in Gulf area. The erosion of vehicles body has an accelerated rate, [11].

The friction and wear of polyethylene (PE) and polypropylene (PP) matrix composites reinforced by unidirectional continuous copper and steel wires were discussed, [12 – 14]. It was found that friction coefficient displayed by the scratch of PE and PP reinforced by copper wires showed slight decrease with increasing number of wires, where the load had insignificant effect on friction coefficient. The change of wire diameter had slight effect on friction coefficient. The hardness decreased close to the wire due to the change of the cooling rate, where the zone near the copper wire was cooling faster and causing a decrease in polymer hardness. Wear of the tested composites slightly decreased with increasing number of wires. Increase of wire diameter showed insignificant effect on wear which significantly increased with increasing normal load. The wear decrease of the tested composites can be explained on the basis that the presence of wire reinforcement can restrain the deformation of the polymer matrix. Besides, plastic deformation, grooving and smearing of surface can be decreased by the strengthening effect of the reinforcement as well as the retarding action of the copper wire against the motion of the indenter.

In the present work, the wear resistance of polyurethane coatings reinforced by steel wires and eroded by sand blast is investigated.

EXPERIMENTAL

Experiments were carried out using sand blast test rig, Fig. 1. It consists of a box of aluminum frame of 120 × 120 × 60 cm^3 dimension. The sand blast gun is fixed to one side of the test chamber at a distance 70 cm far from its bottom. A hopper attached to the sand blast gun contains sand particles. The sand blast gun is connected to an air compressor used to compress atmospheric air up to 0.8 N/mm^2 maximum pressure. The air is stored in a pressure vessel of 25 liters capacity. The compressor is refilled automatically when the pressure decreases to 7 bars. A sand blast gun is used to eject air mixed with sand. When the trigger of the gun is pressed, the air passes from the pressure vessel and creates a suction ejecting the sand particles from the hopper. The average velocity of the air mixed with the sand particles is calculated (30 m/s). The box contains a vise works as specimen holder fixed on a plate of wood which moves through a guide attached to the box frame.



1. Parallel jaw vise.
2. Test Specimen.
3. Nozzle.
4. Hopper contains sand particles,
5. Sand blaster gun,
6. Hose connected to the compressor.

Fig. 1 Sand blast test rig.

Test specimens of steel sheets of 120 × 100 × 2 mm are coated by polyurethane and reinforced by metal wires of 0.4, 0.5 and 0.6 mm diameter, Fig. 2. The test specimens are sand blasted at 90° and the wear is evaluated by the weight loss after test. Two types of wire directions are used; unidirectional and grid. The distance between wires is 2, 4 and 6 mm.

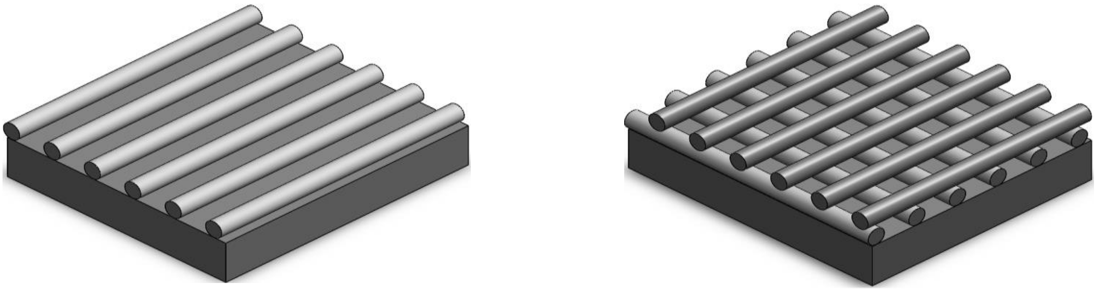


Fig. 2 Test specimens.

RESULTS AND DISCUSSION

Wear decreased drastically with increasing wire diameter, Fig. 3. The lowest wear was detected at 0.6 mm wire diameter. This behavior means that, steel wire strengthened polyurethane coatings. The lowest values of wear were observed when the substrate was coated by polyurethane of 0.5 mm thickness. The evidence of erosion shown in Fig. 4 indicates the accumulation of polyurethane around the steel wire, while the polyethylene layer was removed from the steel substrate.

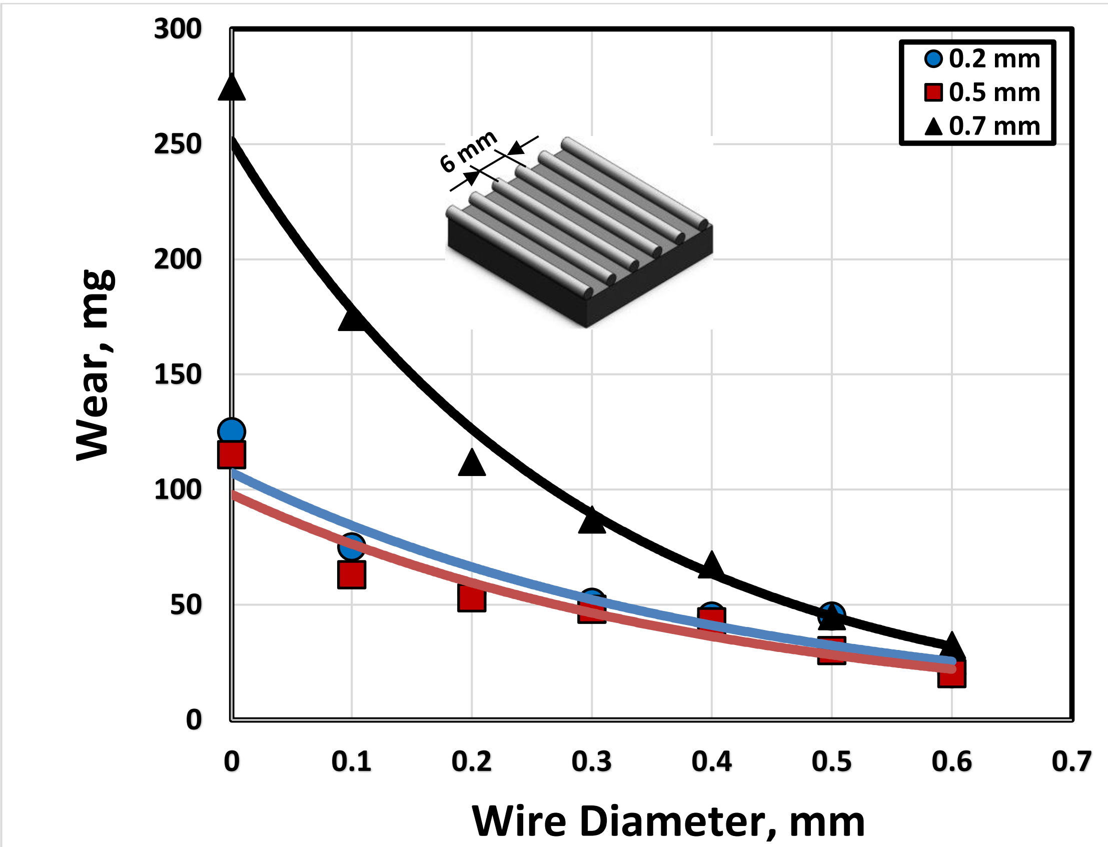


Fig. 3 Wear of polyurethane reinforced by steel wires 6 mm apart.

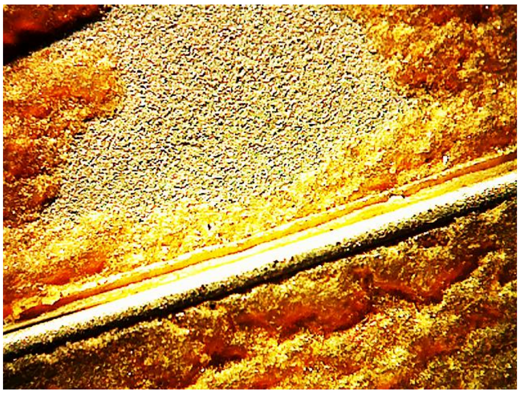


Fig. 4 Surface of the test specimen after erosion.

When the distance between the wires was 4 mm, Fig. 5, wear decreased down to minimum then slightly increased with increasing wire diameter. The lowest wear was observed at 0.5 mm wire diameter. This behaviour can be explained on the basis that, wear decrease is attributed to the increase of the adhesion area between polyurethane and the surface of the steel wires. Lowest values of wear were displayed by the 0.2 mm thickness polyurethane layer. Figure 6 shows that polyethylene coating was removed completely at one side of the steel wire, while the other side was protected by the steel wire keeping polyurethane coating on the steel substrate.

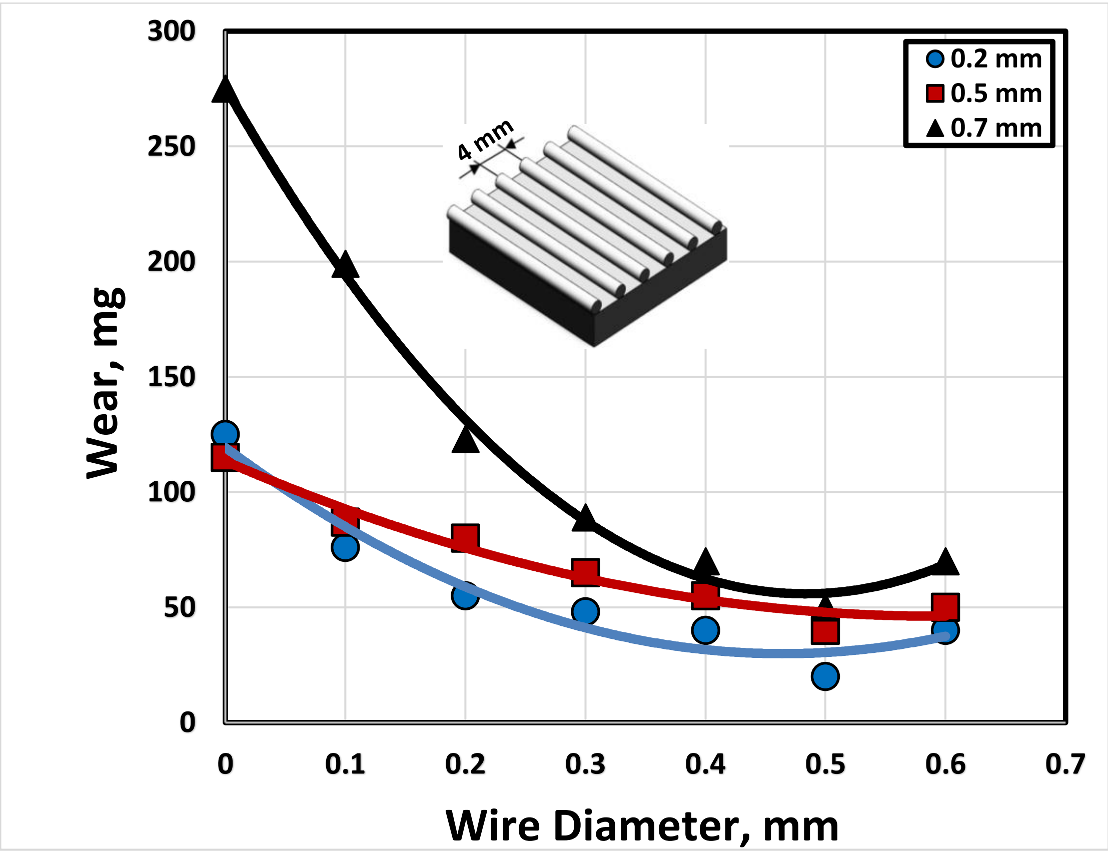


Fig. 5 Wear of polyurethane reinforced by steel wires 4 mm apart.

Fig. 6 Flow of polyurethane around the steel wire.

Polyurethane coating reinforced by steel wires 2 mm apart recorded the lowest wear values, Fig. 7. Coatings of 0.2 mm thickness showed minimum wear at 0.4 mm wire diameter. As the coating thickness increased, wear increased. The evidence of wear is shown in Fig. 8, where less damage was observed due to the strengthening effect of the wires.

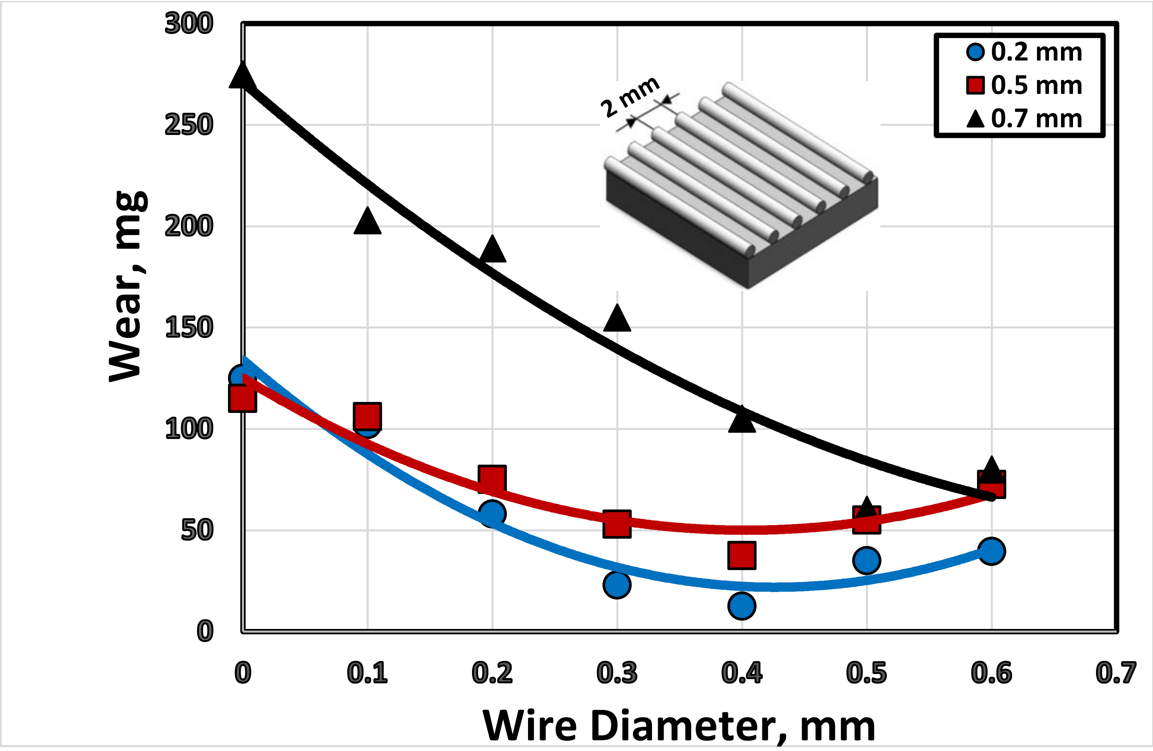


Fig. 7 Wear of polyurethane reinforced by steel wires 2 mm apart.

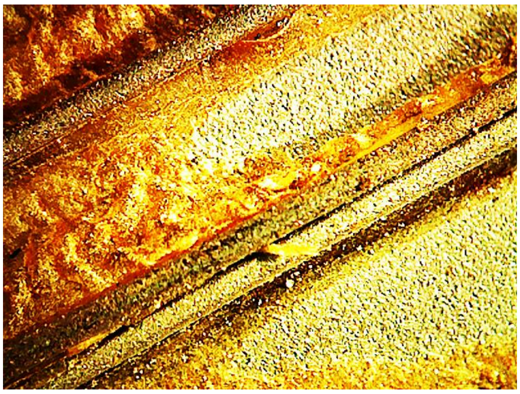


Fig. 8 Effect the impact force on the steel wire.

Wear of polyurethane reinforced by gridded steel wires 6 mm apart, Fig. 9, decreased with increasing wire diameter. At lower values of wire diameter, wear recorded relatively lower values. It seems that in the gridded reinforcement, the adhesion area of polyurethane into the wire surface increased and consequently wear decreased. The distortion in polyurethane coating for gridded reinforcement is shown in Fig. 10, where polyurethane accumulated to the surfaces of the wires. The upper wires are suffered from the embedment of sand particles while the lower wires are suffered from severe abrasion. It is clearly shown that, when decreasing the distance between wire the bonding force increases and wear decreases.

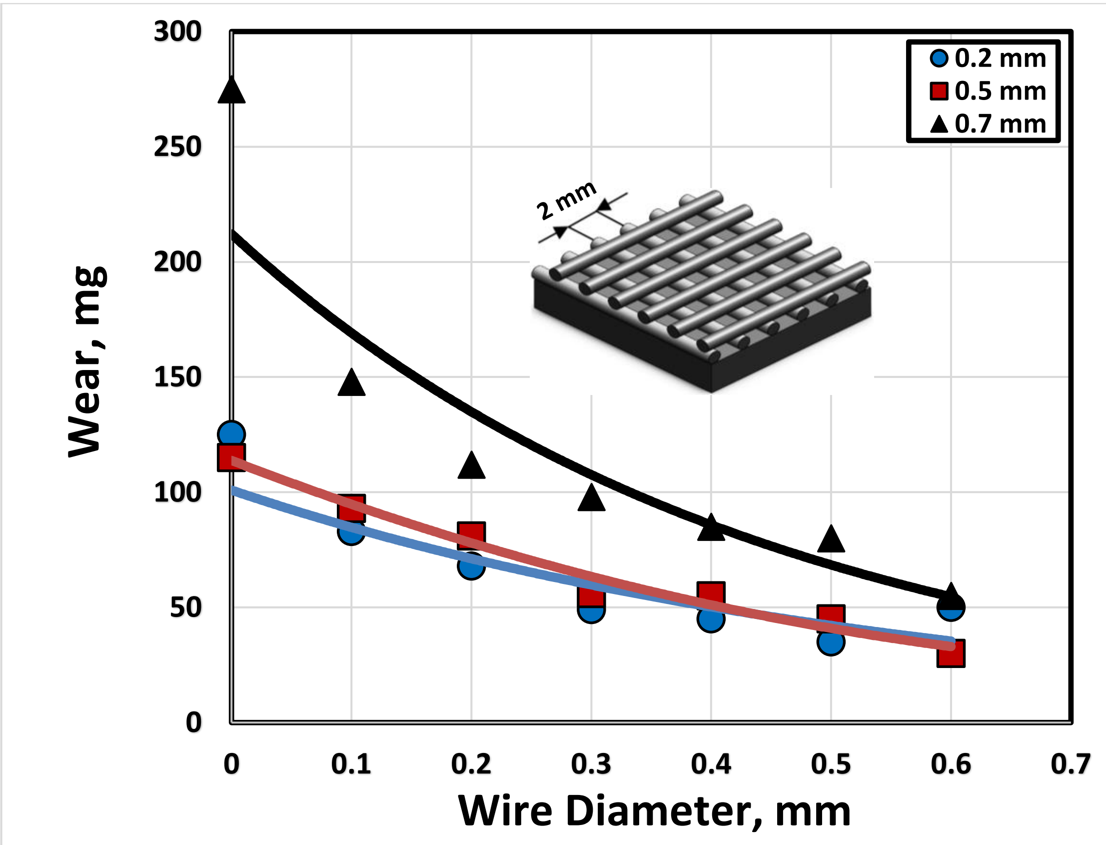


Fig. 9 Wear of polyurethane reinforced by gridded steel wires 4 mm apart.

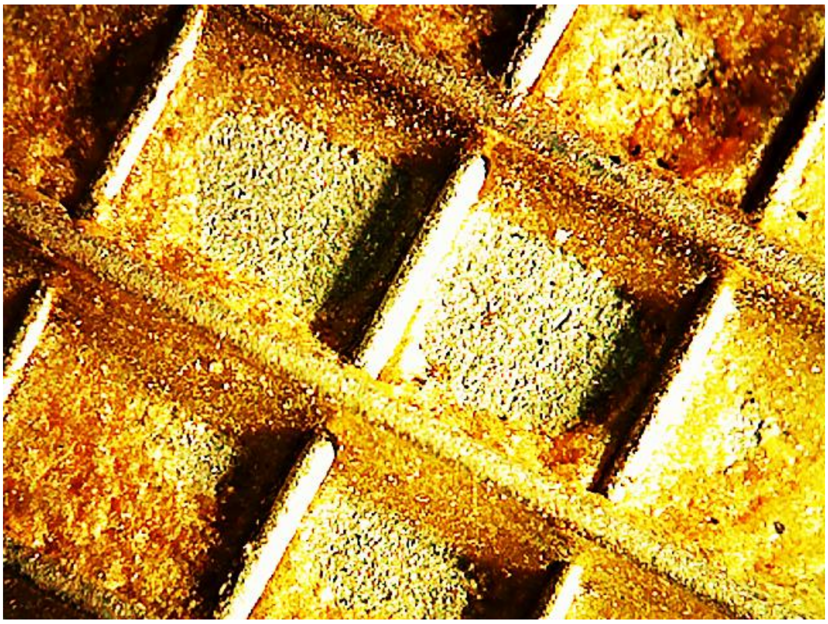


Fig. 10 Accumulation of polyurethane to the sides of steel wire.

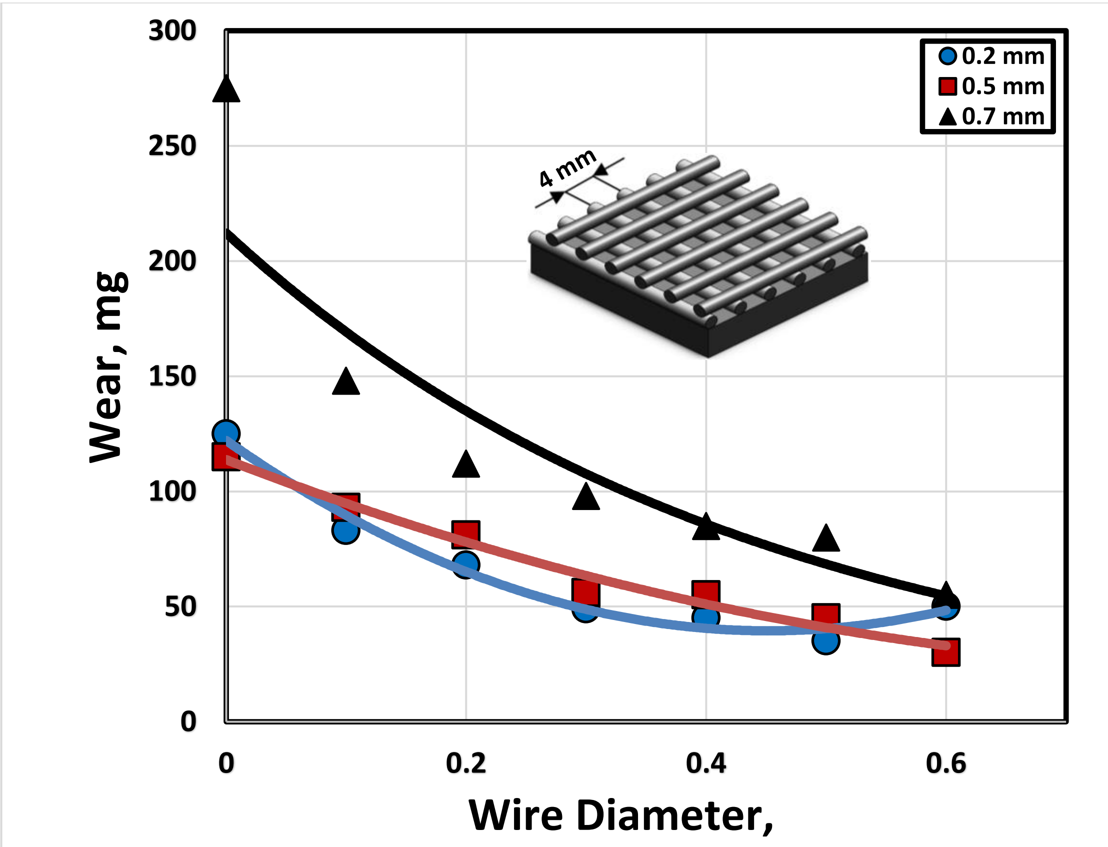


Fig. 11 Wear of polyurethane reinforced by gridded steel wires 4 mm apart.

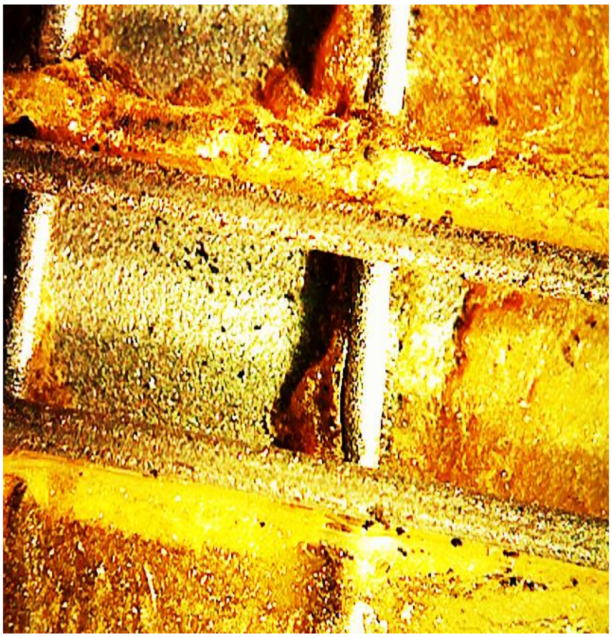


Fig. 12 Erosion of the test specimen reinforced by gridded wires.

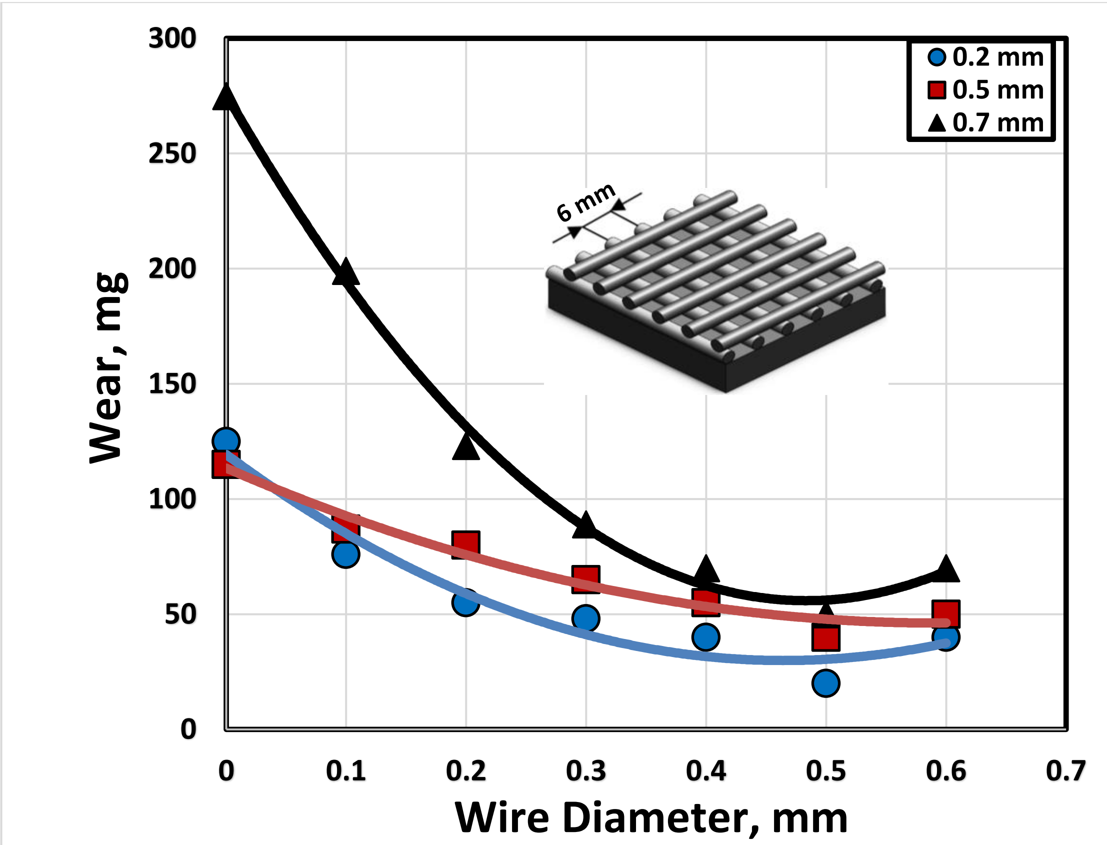


Fig. 13 Wear of polyurethane reinforced by gridded steel wires 2 mm apart.

Fig. 14 Accumulation of polyurethane to the side of steel wire.

The gridded wire reinforcement 4 mm apart showed wear decrease for 0.2 mm polyurethane coating, Fig. 11. Wear decreased gradually with increasing wire diameter. It seems that gridded wire reinforcement strengthened the coating and increased the bonding force between polyurethane and steel wires. The accumulation of polyurethane on one side of the steel wire is shown in Fig. 12. The other side which was adjacent to the erosion of sand particles showed the removal of polyurethane layer from the steel substrate.

Wear of coatings reinforced by gridded steel wires 2 mm apart displayed the lowest values compared to that of 4 and 6 mm distance between wires, Fig. 13. The lowest wear was recorded at 0.5 mm wire diameter for 0.2 mm thickness polyurethane layer. Figure 14 shows that the eroded test specimen after test, where polyurethane accumulated to the sides of the wires. Besides, less surface damage can be noticed due to decreasing distance between wires in the grid, where the resistance to erosive sand particles relatively increased.

CONCLUSIONS

1. Wear of coatings reinforced by longitudinal steel wires decreased drastically with increasing wire diameter. This behaviour means that, steel wire strengthened polyurethane coatings. The lowest values of wear were observed when the substrate was coated by polyurethane of 0.5 mm thickness.

2. When the distance between the wires was 4 mm, wear decreased down to minimum then slightly increased with increasing wire diameter. Lowest values of wear were displayed by 0.2 mm thickness polyurethane layer and 0.5 mm wire diameter.

3. Polyurethane coating reinforced by steel wires 2 mm apart recorded the lowest wear values at 0.4 mm wire diameter. As the coating thickness increased, wear increased.

4. Wear of polyurethane reinforced by gridded steel wires recorded relatively lower values at lower values of wire diameter.

5. The gridded wire reinforcement 4 mm apart showed wear decrease for 0.2 mm polyurethane coating.

6. Wear of coatings reinforced by gridded steel wires 2 mm apart displayed the lowest values compared to that of 4 and 6 mm distance between wires. The lowest wear was recorded at 0.5 mm wire diameter for 0.2 mm thickness polyurethane layer.

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