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DEVELOPMENT OF THE MATERIALS OF DENTURE BASE

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ABSTRACT

The contact and separation as well as friction of materials are accompanied by electrification. When one of the two contacted surfaces is polymeric, the electrification becomes more pronounced. The friction breaks up the rubbing surface and liberates free electrons and ions to generate the electrostatic charge (ESC) on the contacted surfaces. The denture base is made of polymethyl methacrylate (PMMA) that is actively electrostatically charged during attrition with food and teeth. The generation of ESC induces electric field that has drawbacks on the health of human beings. The present work aims to mitigate ESC generated from friction of PMMA by blending with polyethylene (PE) and developing the wear resistance by reinforcing by nanoparticles of silicon carbide (SiC). Experiments have been carried out to measure ESC generated from fiction of the proposed composites. Besides, the scratch test was used to determine friction coefficient and wear at dry condition.

It was found that the highest voltage values were displayed by dry sliding followed by water and salt water wetted surfaces, while olive oil lubricated sliding showed the lowest voltage. As the sliding velocity and load increased, voltage increased. Positive ESC generated from PMMA can be neutralized by blending by 20 wt. % PE. Based on this observation, the magnitude of ESC generated from polymeric materials can be controlled by selecting the proper mixture by the aid of the triboelectric series. In addition, reinforcing PMMA/PE composites by SiC nanoparticles decreased both friction coefficient and wear. It was found that significant decrease in friction coefficient was observed for the PMMA and PE blend. Finally, composites containing 70 wt. % PMMA and 30 wt. % PE showed the lowest wear values. Besides, blended composites reinforced by 1.0 wt. % SiC nanoparticles displayed further lower wear values. It can be concluded that blending PMMA by PE developed the tribological properties and reduce the ESC generated from the sliding on stainless steel (SS).

KEYWORDS
Denture base, polymethyl methacrylate, polyethylene, friction, wear, silicon carbide.

INTRODUCTION

The most extensively material used in manufacturing of denture base is PMMA due to its biocompatibility, [1], as well as color stability and teeth adhesion, [2 – 4]. Experiments were conducted to develop the tribological and mechanical properties of denture base materials, [5, 6]. Reinforcing PMMA by particles and fibers to strengthen the materials was investigated, [7, 8]. Carbon nanotubes (CNTs) have been used to reinforce PMMA to enhance the mechanical properties of the composites due to their resilient and light weight, [9 - 12].

Nanoparticles such silicon oxide, titanium dioxide, aluminum oxide, zirconium dioxide and zinc oxide were applied as filling materials in several biological applications, [13 - 20], because of their antibacterial activity, where the effect of titanium dioxide nanoparticles on friction and wear of dental composite resin was investigated.

Application of polymeric materials in manufacturing denture base raised the need to study the effect of electrification. When two different materials rub each other, free electrons transfer from one surface to the other. Besides, generation of electrons induce electric fields, [21, 22].

ESC generated from the of polymeric coatings on steel was measured, where the effect of sliding velocity and load was tested, [23]. Reinforced polyamide (PA) coatings by metal powders and copper wire was investigated, [24]. Besides, the influence of electric filed on friction and wear was tested, [25]. The sliding of PMMA, polyethylene tetraphthalate (PET), polytetrafuoroethylene (PTFE) and PA against steel was investigated, [26, 27]. The test results showed that ESC increased with increasing sliding velocity in the presence of conducting medium like fresh and salt water.

The present study aims to study the tribological properties such as friction coefficient and wear as well as ESC generated from the sliding of PMMA blended by PE and reinforced by SiC on SS.

EXPERIMENTAL

Experiments were carried out to measure ESC in volts generated from the sliding of the proposed composites on SS. The tested composites consisted of PMMA blended by different contents of PE and reinforced by SiC nanoparticles ranging from 30 to 50 ηm particle size and contents up to 1.0 wt. %. SS was in form of a sheet of 200 mm length, 20 mm width and thicknesses of 0.5 mm, where it represented the counter surface. The test specimens were loaded on SS at 10, 20, 30, 40 and 50 N normal load and slid for 150 mm distance at sliding velocity of 0.1 m/s, where the experiment was repeated five times, Fig. 1. Tests were conducted at dry, olive oil, fresh and salt water (2.0 wt. % NaCl) sliding conditions. ESC in volts was measured by digital milli voltmeter of ± 0.1 mV accuracy.

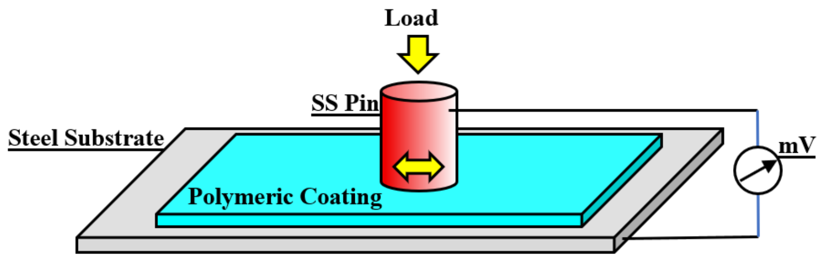

Fig. 1 Measurement of ESC generated from the sliding process.

In order to investigate the tribological properties of the proposed composites, scratch test was conducted to evaluate the wear resistance of the test specimens. Experiments were performed by the scratch test rig, Fig. 2. It contains (titanium carbide) TiC stylus of 0.1 mm tip radius and 2800 kg/mm^2 hardness. Load was 5.0 N applied by weights. Friction coefficient was calculated by measuring the scratch force divided by the normal load. Wear was evaluated by weight loss after scratch by digital balance of ± 1.0 mg. The scratch velocity (2 mm/s) was approximately controlled by turning the screw to feed the stylus in the scratch direction. experiments were performed at 25 ± 2 °C and 50 ± 10 % humidity.

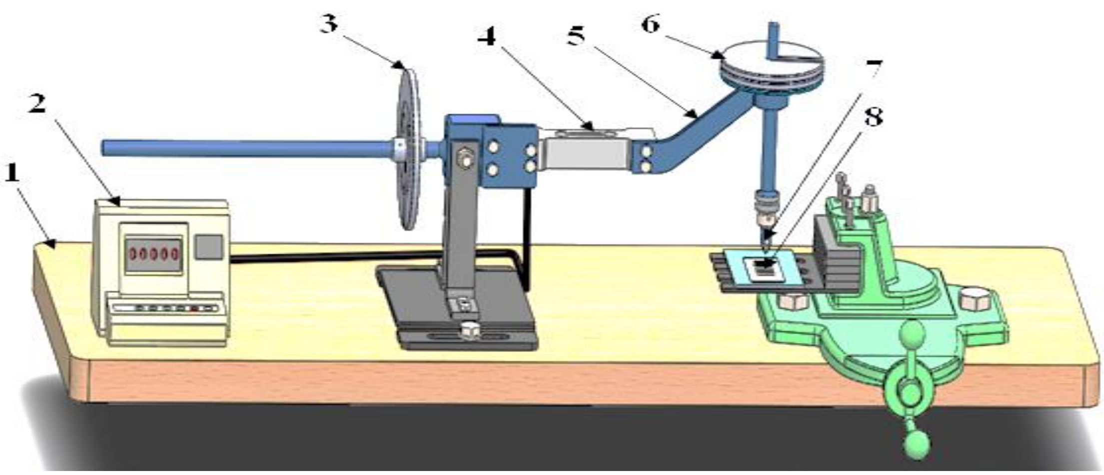

Fig. 2 Scratch test rig,

1. Wooden table, 2. digital screen, 3. counter weight, 4. Load cell, 5. Loading link, 6. Load, 7. Stylus, 8. Test specimen.

RESULTS AND DISCUSSION

The results of the voltage generated from the sliding of PMMA on SS counterface is shown in Fig. 3 at dry, olive oil, fresh and salt water, where voltage significantly increased as the applied load increased due to the increase of the contact area. Dry and water wetted surfaces displayed the highest voltage values. Oil lubricated sliding showed the lowest voltage due to the oil film formed on the contact surface that insulated ESC transfer and mitigated the contact between the two surfaces of

PMMA and SS. The effect of sliding velocity on the voltage values is shown in Fig. 4, where the velocity increase caused remarkable voltage increase.

Based on the triboelectric series, Table 1, it is known that PMMA gained positive ESC when slid on SS, while PE acquired negative ESC. It is aimed in the present work to mitigate ESC by filling PMMA by PE to have the minimum ESC. Figure 5 shows the influence of the PE addition into PMMA matrix on the voltage generated from the sliding. It is seen that the positive voltage measured for PMMA can be neutralized by adding 20 wt. % of PE. This observation can be applied to control the magnitude of ESC generated from polymeric materials by mixing the proper materials of positive and negative ESC using the triboelectric series.

The reduction of the ESC due to blending PMMA by PE can be explained on the bases of their triboelectrification. SS sliding on PMMA generated positive and negative ESC on the surfaces of PMMA and SS respectively according to their ranking in the triboelectric series, Fig. 7, while PE gained negative ESC. Sliding of SS on the blended composites generated positive and negative ESC on the surface of SS, where the charges can be neutralized due to the electrical conductivity of SS. The high magnitude of ESC measured during sliding of SS on PMMA and PE can be reduced by blending the two polymers.

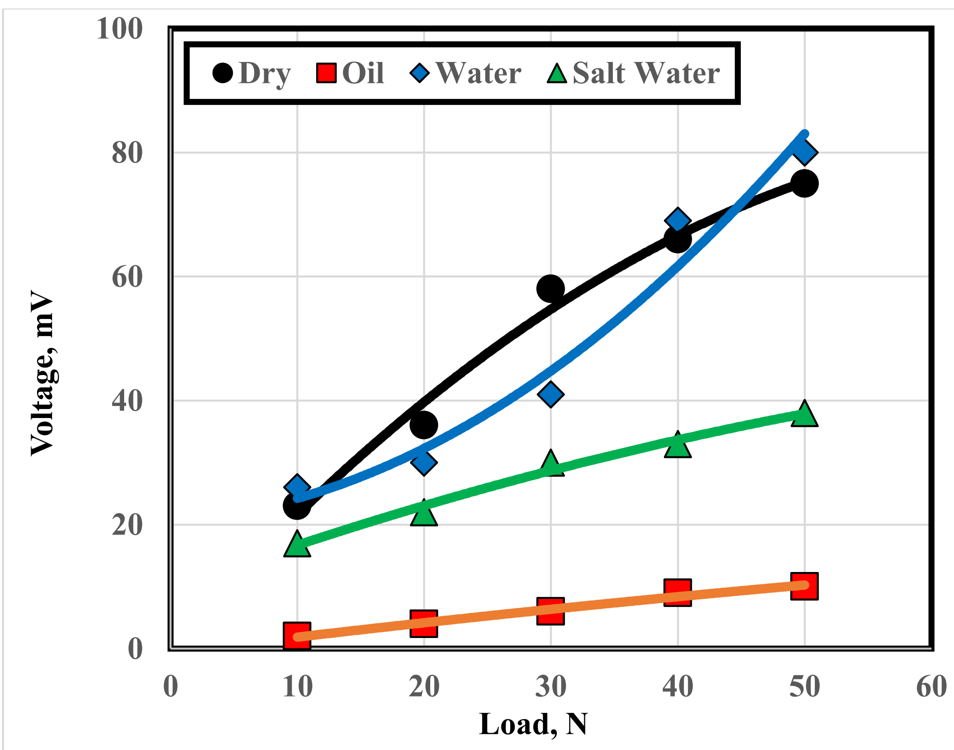

Fig. 3 Voltage generated from the sliding of PMMA on SS.

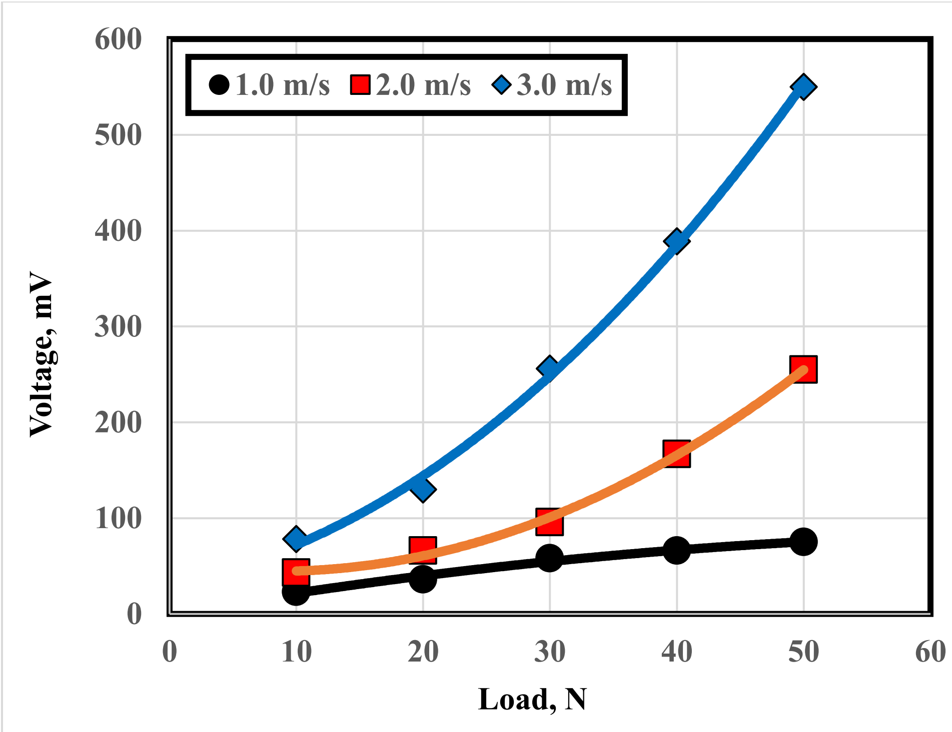

Fig. 4 Voltage generated from the sliding of PMMA on SS at different sliding velocities.

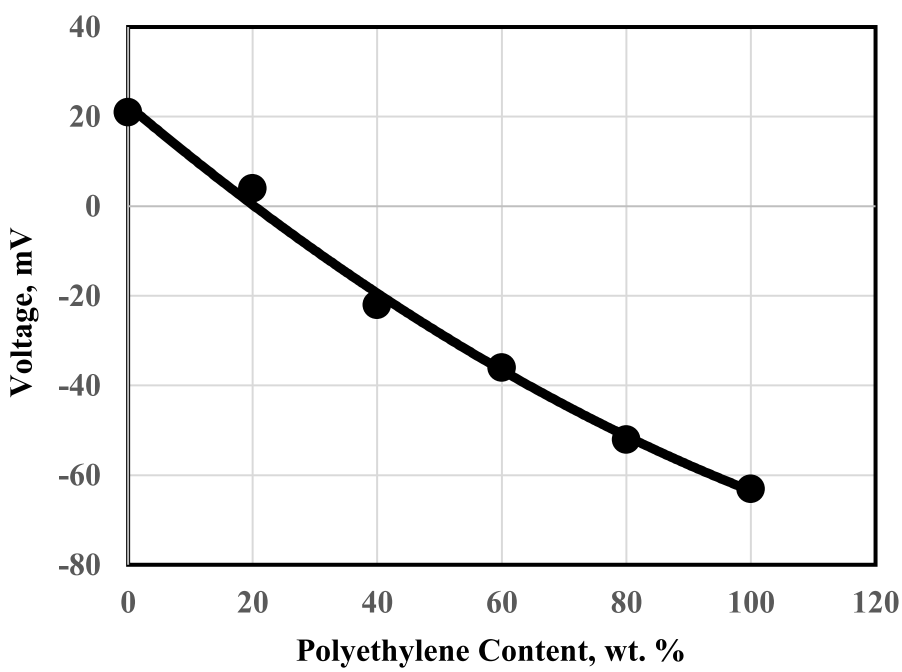

Fig. 5 Voltage generated from the sliding of the tested composites on SS at different PE content.

Table 1 Triboelectric series of the tested materials.

Positive charge
Salt (NaCl)
PMMA
Composite Resin
Stainless Steel (SS)
PE
PP
Polytetrafluoroethylene
Negative charge

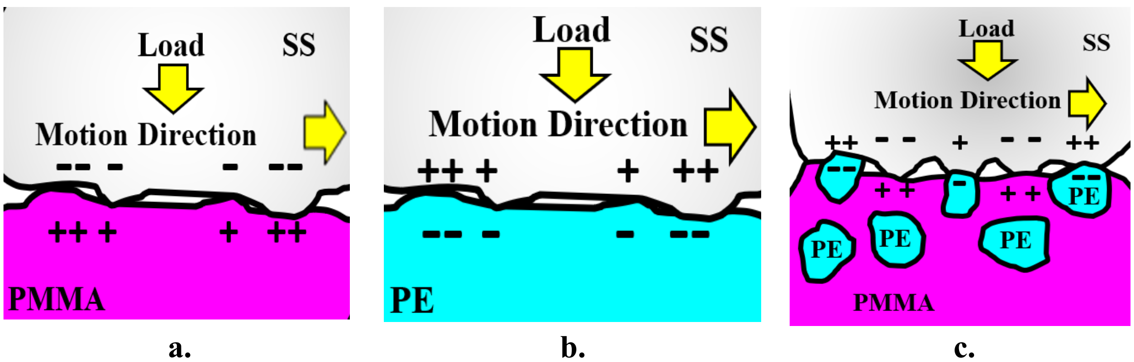

Fig. 6 Generation of ESC on the surfaces of the tested materials.

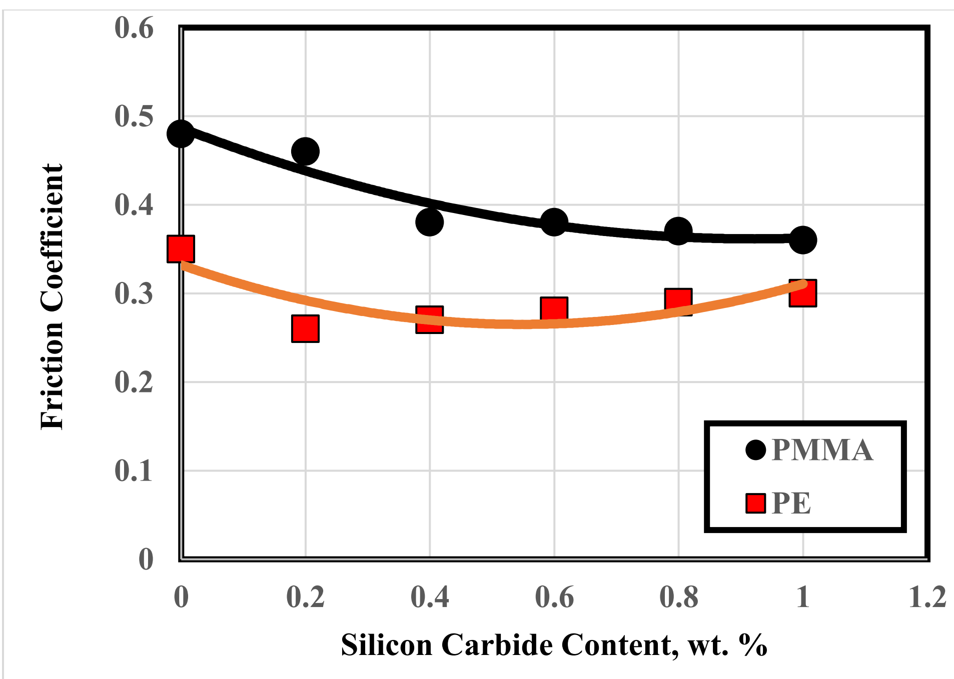

Fig. 7 Friction coefficient of PMMA and PE composites during scratch test.

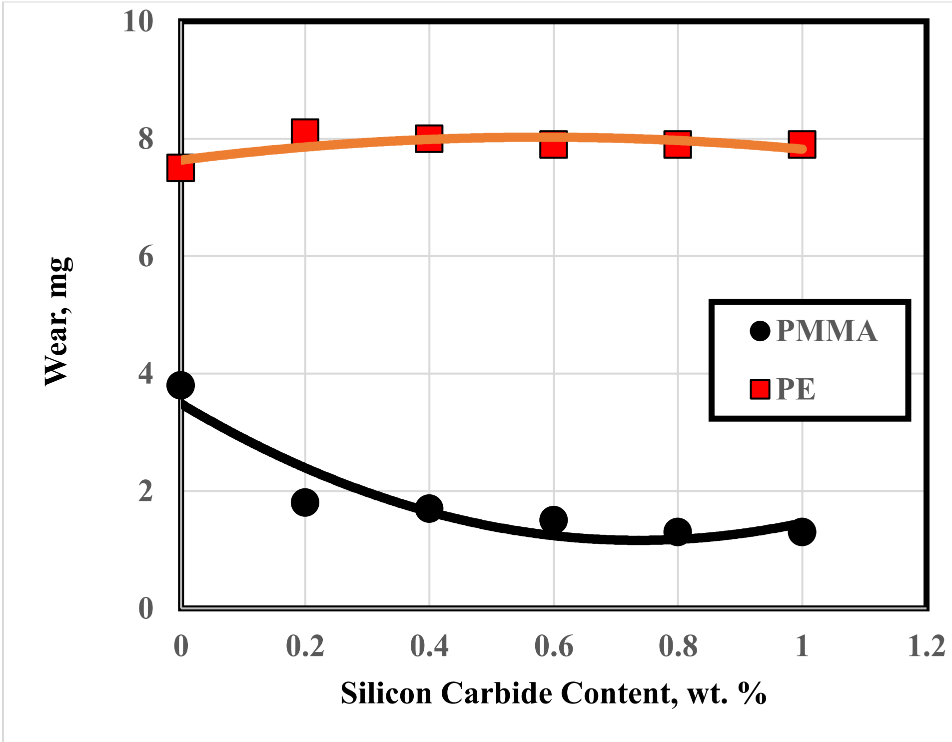

Fig. 8 Wear of PMMA and PE composites after scratch test.

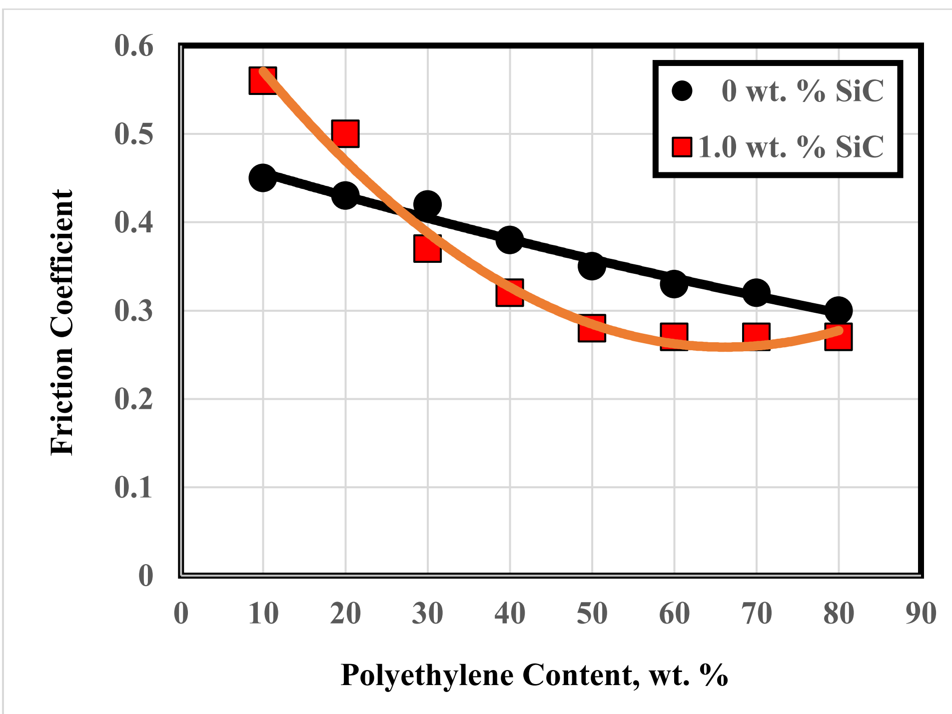

Fig. 9 Friction coefficient of the blend of PMMA and PE during scratch test.

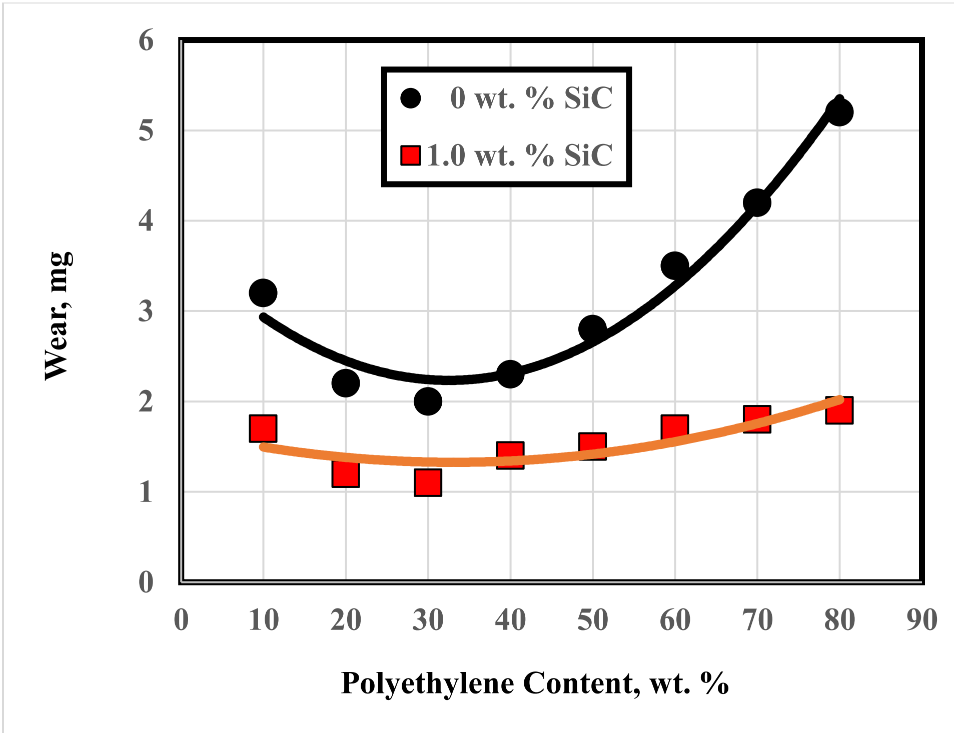

Fig. 10 Wear of the blend of PMMA and PE composites after scratch test.

The evaluation of the wear resistance and frictional behavior of the proposed composites is illustrated in Figs. 7 – 10. The friction coefficient displayed by the scratch of PMMA and PE reinforced by SiC nanoparticles is shown in Fig. 7, where friction coefficient decreased for both PMMA and PE composites compared to the unfilled ones. PMMA composites showed relatively higher friction values than that measured for PE composites. PE composites recorded minimum friction at 0.2 wt. % SiC, while the lowest friction value was shown at 0.4 wt. % SiC content. The reduction of friction values may be attributed to the ability of SiC to mitigate the adherence of both PMMA and PE into the stylus surface so that the friction would be between stylus and SiC nanoparticles. Figure 8 displays the wear of PMMA and PE composites after scratch test, where PMMA composites displayed lower wear than PE composites due to the relatively higher hardness of the PMMA. The influence of the addition of SiC was more pronounced for PMMA where wear recorded slight decrease with increasing SiC content. It seems that SiC nanoparticles formed a layer that protected the polymeric surface from excessive wear.

The friction coefficient and wear displayed by the blend of PMMA and PE composites are illustrated in Figs. 9 and 10 respectively. Blending PMMA by PE caused significant decrease in friction coefficient. Besides, reinforcing PMMA and PE by SiC nanoparticles decreased friction coefficient of the blends due to the ability of SiC to reduce the adherence of the polymer in the insert stylus surface, Fig. 9. Blending PMMA by PE decreased the wear down to minimum then increased with increasing the content of PE, Fig. 10. It is seen that 30 wt. % of PE content displayed the lowest wear values. Further increase in PE content showed significant

wear increase. In addition to that, the blended composites reinforced by 1.0 wt. % SiC nanoparticles displayed lower wear values. The experimental observations confirmed that blending PMMA and PE developed the tribological properties and reduce the ESC generated from the sliding of the proposed composites on SS. Besides, the wear resistance of composites was developed by reinforcing the blended composites by SiC nanoparticles.

CONCLUSIONS

1. Dry sliding displayed the highest voltage values followed by water and salt water wetted surfaces, while the lowest voltages were shown by olive oil lubricated sliding.
2. Voltage increased with increasing sliding velocity and load.
3. Positive ESC generated from PMMA matrix can be neutralized by blending by 20 wt. % PE. This behavior can be used to control the magnitude of ESC generated from friction of polymeric materials.
4. Reinforcing of PMMA and PE by SiC nanoparticles decreased friction coefficient.
5. PMMA composites showed lower wear than PE composites, where the influence of SiC was more pronounced for PMMA.
6. Significant decrease in friction coefficient was observed for the PMMA and PE blend.
7. Reinforcing PMMA and PE by SiC nanoparticles decreased friction coefficient.
8. Composites consisting of 70 wt. % PMMA and 30 wt. % PE showed the lowest wear values.
9. The blended composites reinforced by 1.0 wt. % SiC nanoparticles displayed further lower wear values.
10. The experimental results confirmed that blending PMMA by PE and reinforcing by SiC nanoparticles can develop the tribological properties, wear resistance and reduce the ESC generated from the sliding of the proposed composites on SS.

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