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Tribological Behaviors of SiO_2 Added Polyester Matrix Thermosetting Composites

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In this study, the tribological behavior of polyester matrix composites filled with silicon dioxide (SiO_2) particles is investigated. The tribological characteristics of pure polyester and 10, 20, 30 and 40 wt% SiO_2 filled polyester composites were comparatively evaluated under dry sliding conditions. Wear tests were carried out at room temperature under the loads of 10, 20, and 30 N at the sliding speed of 1 m/s. The wear test results showed that the SiO_2 particles could improve the wear resistance. The friction coefficient of the polyester was getting increased from 0.228 to 1.1052 with an increase in SiO_2 content depending on applied loads. The results showed that the wear rates of pure polyester and SiO_2 filled polyester composites increased with increase in loads. The wear rates of the SiO_2 filled polyester composites were significantly affected from the SiO_2 content. The wear rate of the polyester changed from 8.0×10^{-7} mm^3/m to 1.72×10^{-5} mm^3/m depending on SiO_2 contents and applied loads.

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1. Introduction

The materials must provide unique mechanical and tribological properties combined with a low specific weight and a high resistance to degradation in order to ensure safety and economic efficiency [1]. It is now widely recognized that the friction and wear properties of some polymers may be significantly improved by filling them with organic and inorganic compounds.

Various researchers [2–7] have studied the friction and wear characteristics of polyester filled with compounds such as graphite, Al_2O_3, PbO, CuS, CuO, PbO, PbS, TiO_2, ZrO, and some metal powders. There is relatively little information on the wear behavior of filled thermosetting polymers [8]. Applications of silica particles (SiO_2) are rapidly increasing, not only in the scientific field, but also in the commercial industrial fields. The alteration of material surface properties of SiO_2 particles improves the mechanical properties and durability of materials [9]. Thin polyester films are currently used as substrates in thin flexible displays, touch-screens, and flat panel displays. Some researches have been reported to date on the tribological properties of such top-sheet display components [5]. Fillers have been added to reduce both friction coefficient and wear rate. Studies with epoxy and micron-scale or nanoscale fillers by Xian et al. [10], Friedrich et al. [11], and Zhang et al. [12] show an effective reduction of the wear rate of a polymeric material, and the coefficient of friction with increased filler [13].

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The objective of the present work is the evaluation of the contents of inorganic particles in the tribological behavior of polymeric matrix composites. In order to control easily the production of the specimens, a polyester resin was used as matrix and silica particles were added as inorganic filler.

2. Experimental

The polymer matrix material that is used in this study is polyester "polipol 381" supplied by Poliya Polyester Industry and Trade Ltd. Co. SiO_2 obtained from Subor Pipe Industry and Trade Ltd. Co. was grinded and sieved under 37 μm particle size for sample preparation for the composites. The samples used in the wear test were sectioned as 6 mm in diameter and 25 mm in length from the manufactured composite. The friction and wear tests were realized using pin-on-disk arrangement. AISI 4140 steel disk was used as a substrate material which has 56 HRC hardness and 0.92 μm average roughness (R_a). Wear tests parameters are given in Table.

TABLE

Experimental process parameters of wear tests.

Parameters [units]	Experimental conditions
applied load [N]	10, 20, 30
sliding speeds [m/s]	1.0
temperature [°C]	23 ± 2
humidity [%]	70 ± 1
sliding distance [m]	500
surface roughness, R_a [μm]	0.56

3. Results and discussion

Figure 1a and b presents the variety of coefficient of frictions and contour diagram of pure polyester, 10, 20, 30 and 40 wt% SiO_2 filled polyester at the sliding speed of 1.0 m/s and under the loads of 10, 20, and 30 N for the composites.

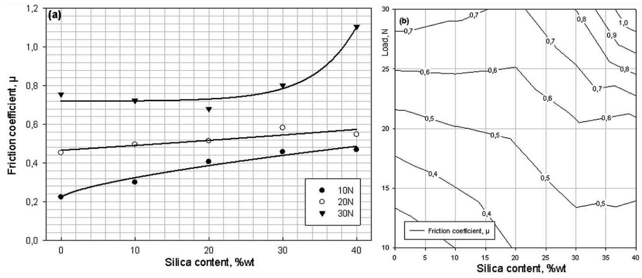

Fig. 1. Variety of (a) coefficient of frictions and (b) contour diagram of pure polyester, 10, 20, 30, and 40 wt% SiO_2 filled polyester at the sliding speed of 1.0 m/s and under the loads of 10, 20, and 30 N for the composites.

As shown from Fig. 1a, increases in the load value for 200% caused the increase of coefficient of friction about 238, 140, 67, 75, and 136% for SiO_2 free, 10, 20, 30, and 40 wt% SiO_2 filled polyester composites, respectively. As shown from the figure, the effect of the applied load is much more effective for the pure polyester than that of the SiO_2 filled composites up to 40 wt% SiO_2 filler content. In general, an increase in the SiO_2 content in the polymer composite resulted in the increase of the friction coefficient linearly. However, 40% SiO_2 filled polymer composite tested under the loads of 30 N caused to dramatically increase the friction coefficient. In order to predict the coefficient of friction of SiO_2 filled polyester composite, contour-diagram of the coefficient of friction was constructed as a function of the filler content and applied load as shown in Fig. 1b. The figure can be used for two purposes. One of them is predicting the coefficient of friction of the samples depending on filler content and applied load. Another is the construction of the composite for pre-determined friction coefficient. Myshkin et al. [14] explained that friction conditions affect the coefficient of friction of the polymers. It is well known that friction is a typical dissipative process in which mechanical energy is converted into heat. The thermal state of friction contact is frequently a decisive factor when evaluating the performance of a friction unit. Romanes et al. [15] explained that the shape and abrasiveness of the wear particles are responsible for the magnitude of the coefficient of friction value. The variation of the wear rate of pure polyester and 10–40 wt% SiO_2 filled polyester based composites with applied load are shown in Fig. 2a and b. Samples are tested at 1.0 m/s sliding speeds under dry sliding condition. These values were calculated from volumetric loss data.

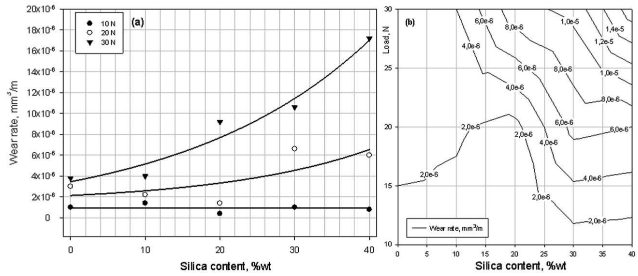

Fig. 2. Variations of (a) wear rate and (b) contour diagram with SiO_2 content depending on applied load and filler content.

Figure 2a shows that the wear rate for pure polyester under dry sliding conditions is in the range of 8.0×10^{-7} and 1.6×10^{-6} mm^3/m. As shown from Fig. 2a, the increase in the load value for a 200% caused the increase of the wear rate about 286, 453, 721, 1099, and 1688% for pure polyester and 10–40 wt% SiO_2 filled polyester included composites, respectively. In order to predict the wear rate of SiO_2 filled polyester composites, contour-diagram of the wear rates was realized as a function of filler content and applied load as shown in Fig. 2b. The figure can be used for two purposes that either predict the wear rates of the samples depending on filler content and applied load or is the construction of the composite for pre-determined wear rate. In general, as shown from Fig. 2a and b, an increase in the SiO_2 filler addition into the polyester causes the increase in the wear rate. Figure 3a and e shows the 10–40 wt% SiO_2 filled polyester composite at the 1.0 m/s sliding speed under the loads of 20 N.

According to Fig. 3, it is possible to say that polyester composite filled with 10–40 wt% SiO_2 includes some abrasive scratches and walls beside the abrasive groves. Wear tracks of the SiO_2 filled composite includes much deeper and dense abrasive groves with increase in filler content. Pure polyester does not includes any abrasive wear and includes some wringless. It is possible to say that the increase in the filler content caused occurring of abrasive particles on the wear track and caused the increase of the composite. As known, SiO_2 is a famous abrasive material and three-body effects of the diversed filler materials caused the decrease of the polymer composites.

4. Conclusions

The following conclusions can be drawn from the present study. Coefficient of friction of polyester and SiO_2 filled (5, 10, 15, and 20 wt%) polyester composites worn against steel surface at the sliding speed of 1.0 m/s under the loads of 10, 20, and 30 N showed that the effect of the applied load is much effective for the SiO_2 filled composites than that of the pure polyester and increase in the SiO_2 content in the polymer resulted in the increase in the friction coefficient. Wear rates of the samples showed that filler content increases caused an increase of wear rate of the polyester composites, effectively. Polyester composite filled with 10–40 wt% SiO_2 includes some abrasive scratches and walls beside the abrasive groves. Wear tracks of the SiO_2 filled composite includes much deeper and dense abrasive groves with increase in filler content. Pure polyester does not include any abrasive wear and includes some wrinkles.

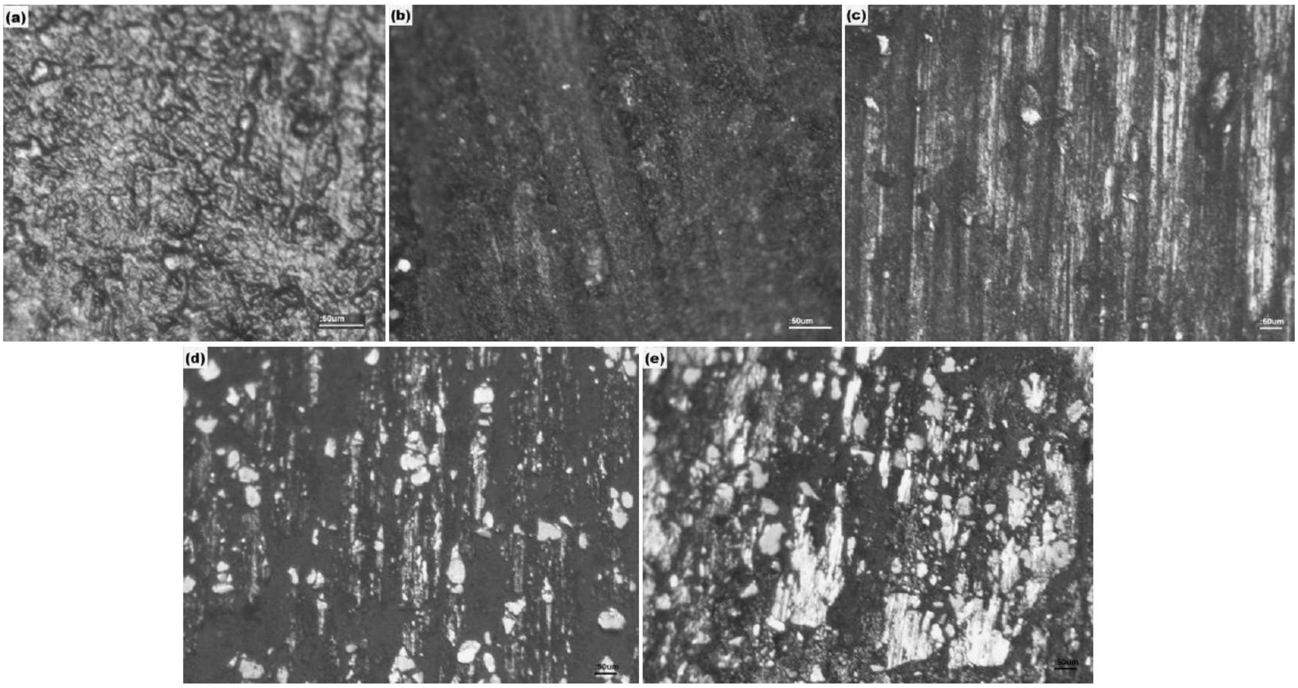

Fig. 3. Optical micrographs of worn surfaces of (a) pure polyester, (b) 10% SiO_2, (c) 20% SiO_2, (d) 30% SiO_2, (e) 40% SiO_2 filled polyester composite, under the load of 20 N.

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