NOTE

Tribological Properties of PTFE-Filled PMIA

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Received 19 January 1999; accepted 9 February 1999

ABSTRACT: The polytetrafluoroethylene-filled (PTFE) poly(*m*-phenylene isophalamide) (PMIA) composite blocks are prepared by compression molding. The friction and wear of PTFE-filled PMIA are investigated on a block-on-ring machine by running the PMIA composite block against plain carbon steel (AISI 1045 steel ring). The worn surface of PMIA composite and the steel counterface are examined by using electron probe microanalysis (EPMA). It is found that PTFE-filled PMIA exhibited considerably lower friction coefficient and wear rate than pure PMIA. Furthermore, the lowest wear rate is obtained when the composite contains 20 vol % PTFE. EPMA investigations show that there are some debris that could restrain the wear of the PMIA composites oriented along the sliding track and embedded in the surface of PMIA composite. A kind of stripe transfer film that contains abundant F element should be the main reason for the improvement of the tribological properties of PTFE-filled PMIA composites. © 1999 John Wiley & Sons, Inc. J Appl Polym Sci 74: 747–751, 1999

Key words: PMIA; friction; wear; PTFE; surface analysis

INTRODUCTION

Polyamide and its composites attract extensive concern by tribological scientists worldwide. Most of the research done in this field has focused on fatty polyamides.[1–5] There have been few studies on friction and wear characteristics of aromatic polyamides such as poly(*m*-phenylene isophalamide) (PMIA) because they are usually used as a fiber.[6–9] The polytetrafluoroethylene (PTFE) has been added to improve the tribological properties of PMIA. However, few scientists study the mechanism of friction and wear behavior of the PTFE-filled PMIA. Therefore, the friction and wear behavior of PTFE-filled PMIA and the mechanism of the friction and wear behavior of PMIA was also studied in this work.

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Journal of Applied Polymer Science, Vol. 74, 747–751 (1999)

CCC 0021-8995/99/030747-05

EXPERIMENTAL

PMIA was produced by Oiles Corporation in Japan. PTFE was produced by Jinan Chemical in China. The PMIA powder was fully mixed with the PTFE by the use of a high-speed dispersing instrument. The mixture was then dried at 100°C for 2 h to remove the moisture. The block specimens for friction and wear tests were prepared by compression molding during which the mixture was heated at a rate of 5°C/min^{-1} to 330°C, held there for 15 min, and then cooled to room temperature. In this experiment, a MM-200 model friction and wear tester was used as shown in Figure 1. Before each test, the surface of the steel ring and PMIA composite block were polished with number 900 water-abrasive paper, cleaned with cotton dipped in acetone, and air-dried. The morphologies of the wear traces were observed using a Model EMP-810 electron probe microanalysis.

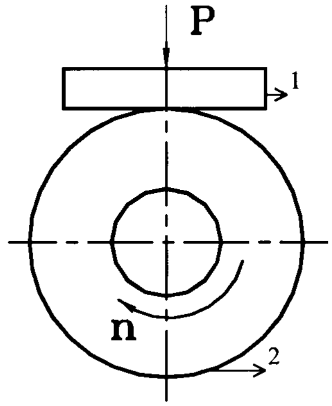


Figure 1 The contact schematic diagram for the friction couple. P: Load; 1: sample; 2: rotating ring.

RESULTS AND DISCUSSION

Bending Strength of PMIA Composites

Figure 2 shows the bending strength of the composite as a function of PTFE contents in PMIA, which is almost linearly decreased with increasing PTFE content. The lowest bending strength in this experiment was reached when the PTFE content reached 50 vol %.

Friction and Wear Properties of PMIA Composites

Figures 3 and 4 show the friction coefficient and wear rate of PTFE-filled PMIA as a function of PTFE content. Note that the friction coefficient decreases sharply when PTFE content is <5 vol %. It then decreases gently with increasing PTFE content to 50 vol %. In the meantime, the PTFE-filled PMIA composite exhibits a

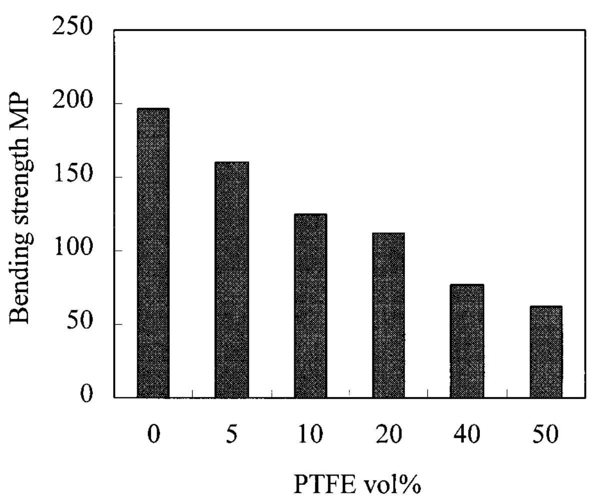


Figure 2 Effect of PTFE content on the bending strength of the filled PMIA.

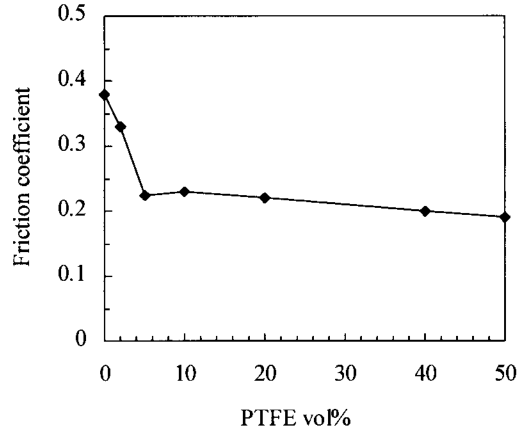


Figure 3 Effect of PTFE content on the friction coefficient of the filled PMIA. (Sliding was performed under ambient conditions over a period of 120 min at a sliding speed of 0.42 m/s and a load of 196*N* at room temperature.)

decreased wear rate in comparison to the unfilled one. However, the wear rate does not linearly relate to the PTFE content. The wear rate of the composite decreases with the increase in PTFE content to 20 vol %. Then the wear rate of the composite increases with the PTFE content to 50 vol %. The reason the wear rate of the composite with PTFE > 20 vol % increases is that the mechanical strength of PTFE-filled PMIA composite became too low, which indicates that mechanical strength is the factor determining the tribological behavior of materials.[5] In the combination of tribological properties and mechanical strength, we recommend that the optimal content of PTFE in the composite be 20 vol %.

Effect of Load on Tribological Properties of PMIA Composites

Figures 5 and 6 show the effect of load on the coefficient of friction and wear rate of PMIA composites-filled

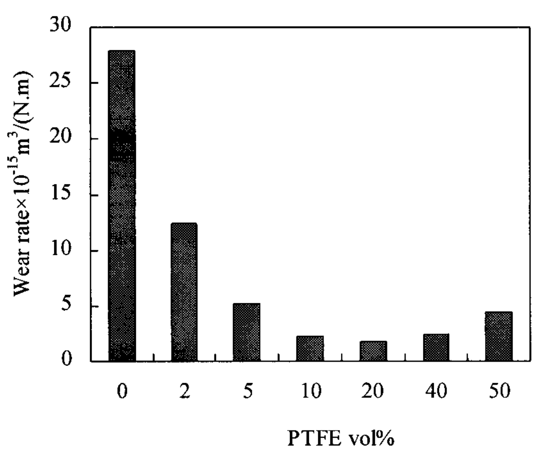


Figure 4 Effect of PTFE content on the wear rate of the filled PMIA.

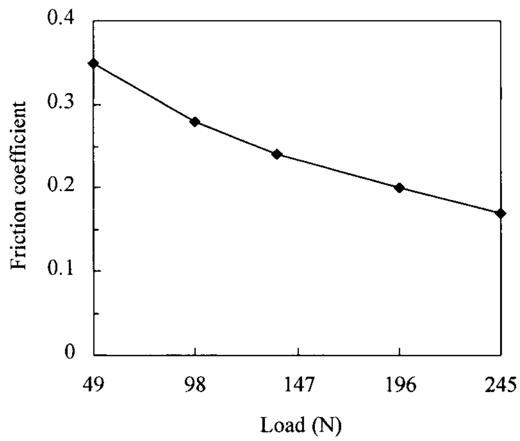


Figure 5 The friction coefficient as a function of the filled PMIA for various loads (sliding speed: 0.42 m/s).

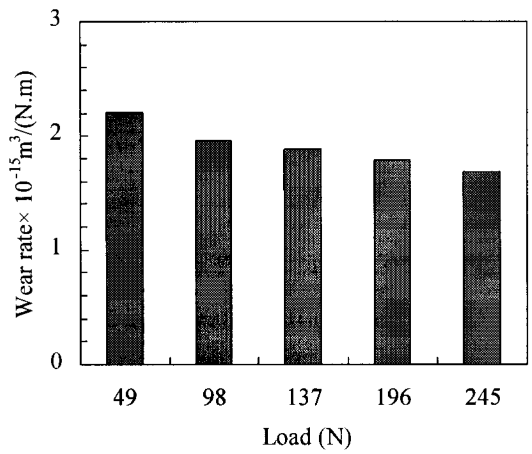


Figure 6 The wear rate as a function of the filled PMIA for various loads (sliding speed: 0.42 m/s).

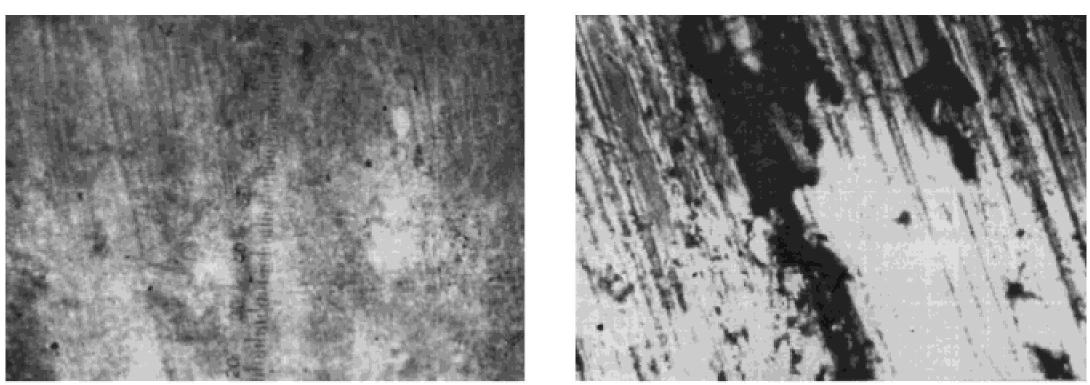
PTFE, which is decreased with increasing load. The lowest friction coefficient and wear rate in this work is obtained under a load of 245*N* and indicates that PTFE is more effective for improving the trigological properties of the composite at a high load.

SEM Analyses

Figure 7 shows the optical micrographs of the worn surface of the 20% PTFE-filled PMIA block before and after testing. Some dark brown debris was observed oriented along the sliding track and embedded in the surface of PMIA composite with obvious grooves on the worn surface.

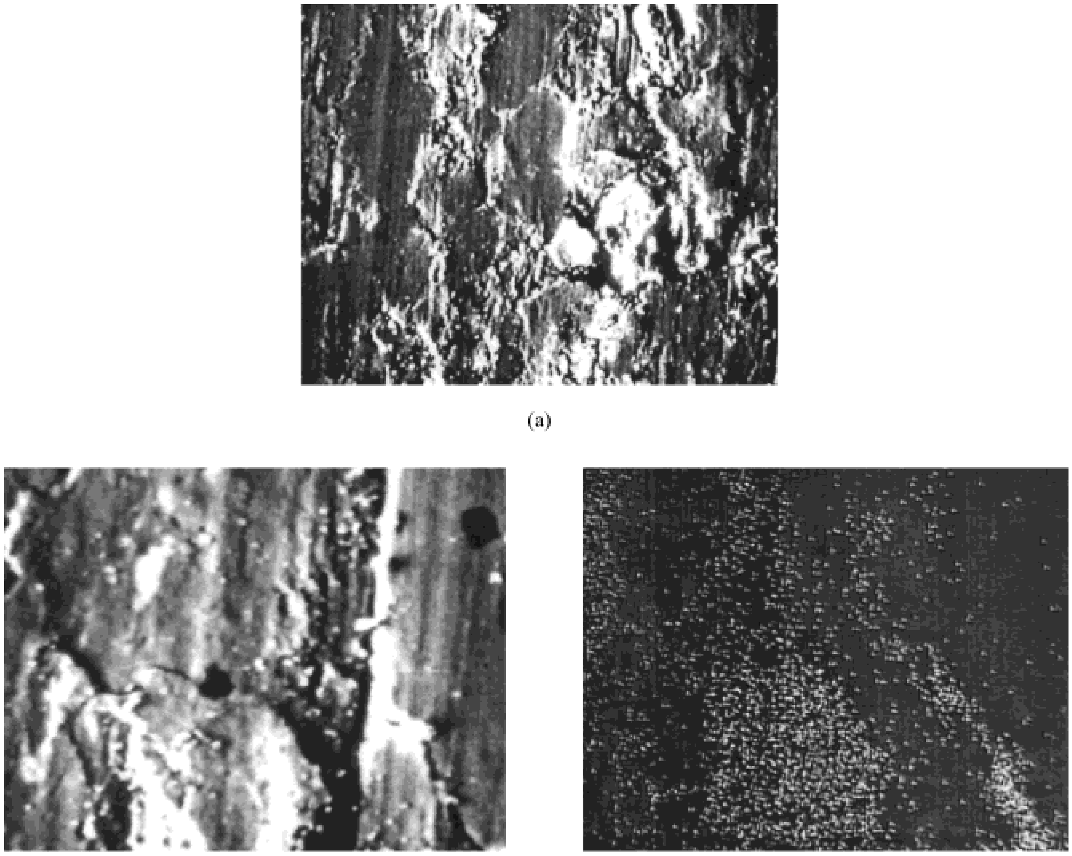
A SEM picture of the worn surface of the PMIA composites is given in Figure 8(a). Figure 8(b) is the corresponding high magnification picture. Figure 8(c) gives the related Fe element distribution on the worn surface. Figure 8(a, b) shows more clearly the embedded debris on the surface of PMIA composite with a lot of cracks on the worn surface. It has been found that the Fe element in the area of embedded debris is > other areas [Fig. 8(c)], which indicates that the embedded debris may undergo the following process. The debris transfers to the coupling ring from the PMIA composites, then transfers back to the worn surface of the PMIA composites and is embedded in the worn surface under the load and friction force. The embedded debris could restrain the wear of the PMIA composites. In addition, the cracks of the worn surface of the PMIA composites could be formed under a friction process because of the bad compatibility between the molecules of PMIA and PTFE.

A SEM picture of the worn surface of the ring is given in Figure 9(a). Figure 9(b) is the corresponding high magnification picture. Figure 9(c) gives the related F element distribution on the worn surface of the ring. A kind of stripe transfer film that oriented along the sliding direction is formed on the ring. Fe element distributes more in the area of stripe film than in the other area, which indicates that the transfer film con



(a) (b)

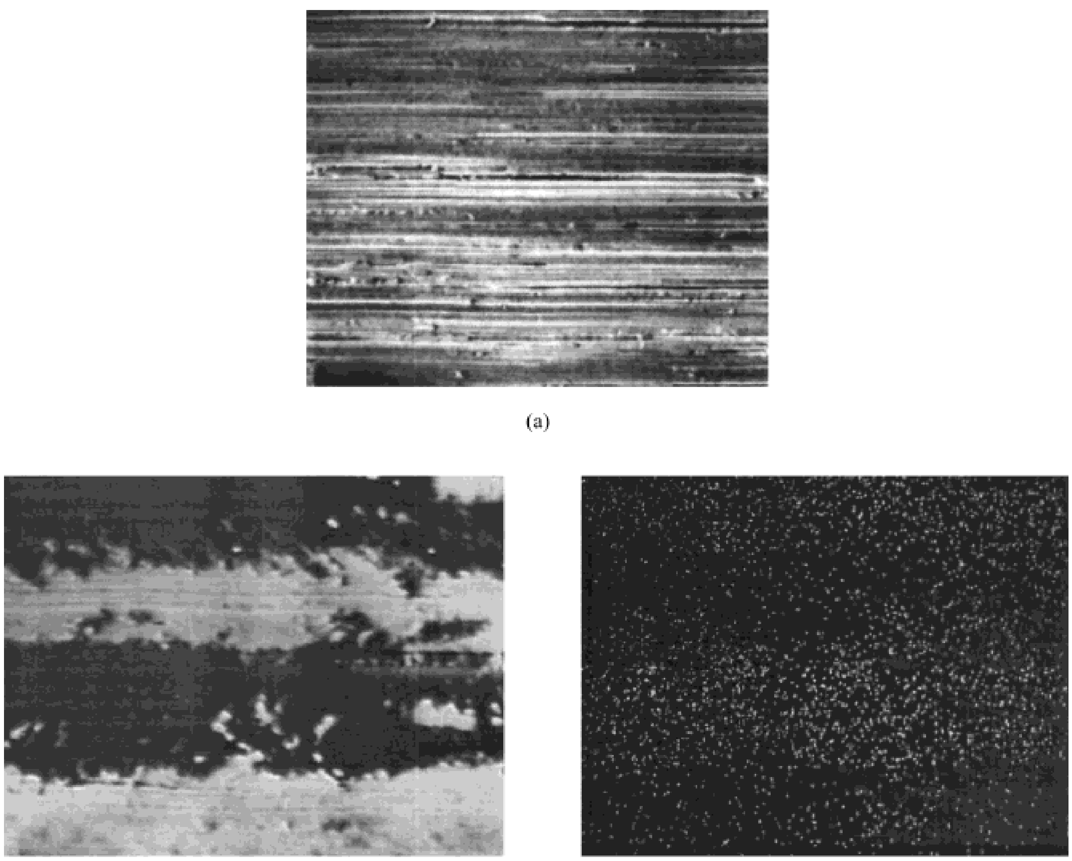
Figure 7 Optical micrographs of the (a) original and (b) worn surface of 20 vol % PTFE-filled PMIA.



(a)

(b) (c)

Figure 8



(a)

(b) (c)

Figure 9

Figure 8 SEM of worn surface of 20 vol % PTFE-filled PMIA and Fe element distribution map.

Figure 9 SEM of worn surface of counterpart ring and F element distribution map.

tains abundant F elements on the ring and may be the main reason for the improvement of the tribological properties of PTFE-filled PMIA composites.

CONCLUSIONS

It is found that PTFE-filled PMIA exhibited considerably lower friction coefficient and wear rate than pure PMIA. Furthermore, the lowest wear rate is obtained when the composite contains 20 vol % PTFE. There is some debris that could restrain the wear of the PMIA composites oriented along the sliding track and embedded in the surface of PMIA composite. A kind of stripe transfer film that contains abundant F element should be the main reason for improving the tribological properties of PTFE-filled PMIA composites.

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