Vol. 39, No. 4 (2017) 482-486, DOI: 10.24874/ti.2017.39.04.07

Tribology in Industry

www.tribology.fink.rs

RESEARCH

Effect of Different Fillers on Adhesive Wear Properties of Glass Fiber Reinforced Polyester Composites

E. Feyzullahoğlu

University of Kocaeli, Faculty of Engineering, Department of Mechanical Engineering, Umuttepe, Kocaeli, Turkey.

Keywords:

Glass Fiber
Polyester
Filler Materials
Adhesive Wear

Corresponding author:

Erol Feyzullahoğlu
University of Kocaeli,
Faculty of Engineering,
Department of Mechanical Engineering,
Umuttepe, Kocaeli, Turkey.
E-mail: feyzullahoglu@yahoo.com

ABSTRACT

Polymeric composites are used for different aims as substitute of traditional materials such as metals; due to their improved strength at small specific weight. The fiber reinforced polymer (FRP) composite material consists of polymeric matrix and reinforcing material. Polymeric materials are commonly reinforced with synthetic fibers such as glass and carbon. The glass fiber reinforced polyester (GFRP) composites are used with different filler materials. The aim of this study is to investigate the effects of different filler materials on adhesive wear behavior of GFRP. In this experimental study; polymetilmetacrilat (PMMA), Glass beads (GB) and Glass sand (GS) were used as filling material in GFRP composite samples. The adhesive wear behaviors of samples were carried out using ball on disc type tribometer. The friction force and coefficient of friction were measured during the test. The volume loss and wear rate values of samples were calculated according to test results. Barcol hardness values of samples were measured. The densities of samples were measured. Results show that the wear resistance of GB filled GFRP composite samples was much more than non-filled and PMMA filled GFRP composite samples.

1. INTRODUCTION

Composites consist of two or more materials with different physical or chemical properties. It is classified as “matrix” or “reinforcement”. Composites are commonly used because of their evident features such as low density, high rigidity, high strength, non-corrosive, thermal and electrical insulation properties. It can also be machined like wood using metal cutting tools.

When extra strength is needed, many types of plastics can be reinforced. The combination of plastic and reinforcement material can produce some of the strongest and most versatile materials. The fiber reinforced polymer (FRP) composite material consists of polymer matrix resin, sometimes referred to as plastic, (either thermoplastic or thermoset resin, such as polyester, isopolyester, vinyl ester, epoxy, phenolic) and synthetic fiber reinforcement material such as glass, carbon, aramid. Polyesters are also generally used as matrix materials, especially with glass fibre reinforcement. Polyester is an economic material. It has resistance to environmental and chemical effects. And it has high dimensional stability and low moisture absorption [1]. Glass and carbon fibers are mostly used as reinforcements because of their low expansion rate and high flexural modulus [2]. The fiber reinforced polymer (FRP) composite may also contain fillers, additives and core materials. These matters modify and enhance the final product.

The different filler materials are used in glass fiber reinforced polyester (GFRP) composites. Filler materials are usually the inactive materials which are used in composite materials to decrease material costs, to improve mechanical properties and to improve process ability.

Adhesive wear is a phenomenon in which the sliding surfaces are been in contact. Adhesive wear is dependent on several physical and chemical factors such as material properties and presence of chemicals. It is dependent on the dynamic factors such as the velocity and applied load in addition.

The improvement of the tribological properties of a polymer composite with the combination of fibers/fillers is well known. This event showed both positive and negative conclusions on the tribological properties of a polymer composite. Fillers as reinforcing material have been carried by various researchers. Many studies on the sliding wear mechanism of GFRP composites have been carried out in literature. Mohan et al. investigated abrasive wear behavior of hard powders such as tungsten carbide (WC) and tantalum niobium carbide (Ta/NbC) filled glass fabric–epoxy hybrid composites [3]. They obtained that the hard powders filled composite samples exhibited lower wear volume loss and lower specific wear rate as compared to unfilled composite samples. Quintelier et al. investigated self-lubricating and self-protecting properties of polymer composites for wear applications [4]. They determined the formation of a lubricating film, in relation to glass fibers. This film resulted in a lowering of the coefficient of friction and indicated the importance of a good implementation of composite materials for bearing applications. Pihtili examined the effects of resin content on the wear of woven roving glass fibre–epoxy resin and glass fibre–polyester resin composite materials [5]. He obtained that glass fibre–epoxy resin composites generally showed higher strength and minimum wear when compared with glass fibre–polyester resin composites materials. Pıhtılı and Tosun investigated the wear behavior of a glass-fibre-reinforced composite and plain polyester resin under various loads, speeds and sliding distances [1]. They stated that the wear resistance of the fibre glass-reinforced composite samples was much more than the plain polyester. Chand et al. studied short glass fiber reinforced polyester composites with and without filler at low stress abrasive wear conditions [6]. They stated that glass fibers provided better resistance against wear and high weight fraction of glass fiber in the composite showed less wear loss as compared to composite containing less glass fibers. Singh et al. developed bi-directional E-glass fibre-based polyester composites filled with zinc oxide (ZnO) and titanium dioxide (TiO_2) fillers [7]. They observed that TiO_2 filled composites had better perform than ZnO filled composites under abrasive wear situations. Shibata et al. investigated the tribological behavior of Polyamide 66 (PA66) resin composites containing rice bran ceramics (RBC) particles or glass beads (GB) at a wide range of normal loads and sliding velocities under dry condition [8]. They stated that PA66/GB composites showed low friction and low wear compared with pure PA66. GB particles prevented the formation and growth of roll-shaped particles on the wear track which was resulted in low wear.

2. MATERIALS AND METHOD

2.1 Tested materials

The chemical compositions and densities of GFRP samples using in experimental study are given in Table 1 and 2.

Table 1. Contents of test samples.

Sample	Chemical concentrations of samples
Non-filled	Polyester + 10 wt.% Glass Fiber
GB filled	Polyester + 10 wt.% Glass Fiber + 10 wt.% Glass Beads
GS filled	Polyester + 10 wt.% Glass Fiber + 10 wt.% Glass Sand
PMMA filled	Polyester + 10 wt.% Glass Fiber + 10 wt.% PMMA

Table 2. The density of samples.

Sample	Density (g/cm^3)
Non-filled	1.78
GB filled	1.77
GS filled	1.77
PMMA filled	1.61

Polymetilmetacrilat (PMMA) is a transparent thermoplastic polymer which has good resistance for atmospheric conditions with low water absorption, dimensional stability, mechanical strength and rigidity [9]. Also it has hardness and resistance to scratching. It is used in automotive and glass applications [10]. Depending by compositions, sizes, T_g and molecular weights PMMA also can be used as matting and thickening agent in different applications.

Glass beads (GB) have importance as filler in the production of polymer in recent years. It has been developed for chemical processes, energy production, agriculture and pharmaceutical industries [11]. It is used to reduce density and fluidity in polyester and epoxy composite materials. It has lubrication property and wear resistance in polymer materials. It is used as alternatives to conventional fillers and additives such as silica, calcium carbonate, talc and clay.

Glass sand (GS) is used as filler and durability materials in polymer composites. It has usually average of 30 μm grain size. It is resistance to scratching and fire.

2.2 Testing procedures

The Bulk Moulding Compound (BMC) method was used together balances and mixers for adding fillers to samples. In sample preparation, the GFRP samples were produced by hot-compression molding at 140 °C, 150 bar for 3 min. The used glass fibers in samples have 13 μm diameter and 12 mm length. GFRP samples were provided by Sami Tongün Glass Fiber Polyester Products, Kocaeli/Turkey for experimental studies. The samples having size of 20x20x4 mm were cut from the plate for wear tests (Fig. 1). The adhesive wear behaviors of samples were carried out using ball on disc tribo-testing machine (Nanova Tribometer) (Fig. 2). In tribometer, the ceramic ball with radius of 3 mm was fixed on the load arm and the sample was placed on a rotating disc (250 rpm) with a friction radius of 5 mm (Fig. 3). In all wear tests, the load and sliding distance was fixed at 5 N and 80 m, respectively. Testing parameters was selected according to tested materials properties and tribo-testing machine operation conditions. Each sample was tested at least three times. The friction force and coefficient of friction were measured during the test.

Examinations of occurred wear traces during the wear test were performed by using Nikon SMZ 745T light microscope. The volume loss and wear rate values of samples were calculated according to test results. Hardness values of samples were measured by using Zwick Barcol Tester. All tests are performed at a constant room temperature (20 °C).

Fig. 1. Tested samples.

Fig. 2. Nanova Tribometer.

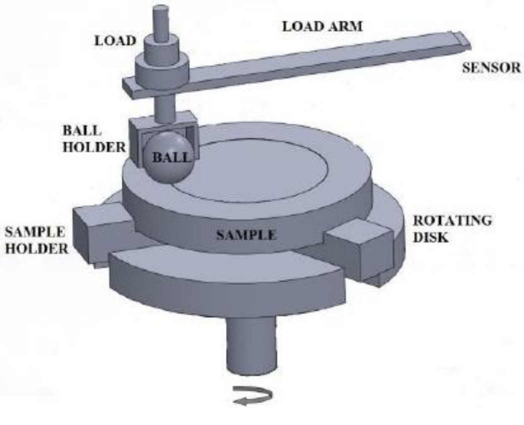

Fig. 3. Wear mechanism.

3. RESULTS AND DISCUSSION

Figure 4 shows coefficient of friction values of samples. The coefficient of friction is also dependent on the production of the thin polymer film on the wear surface. PMMA filled sample has the most coefficient of friction value in the samples. As the glass beads (GB) has lubrication properties, GB filled sample has lowest coefficient of friction values in the samples [11].

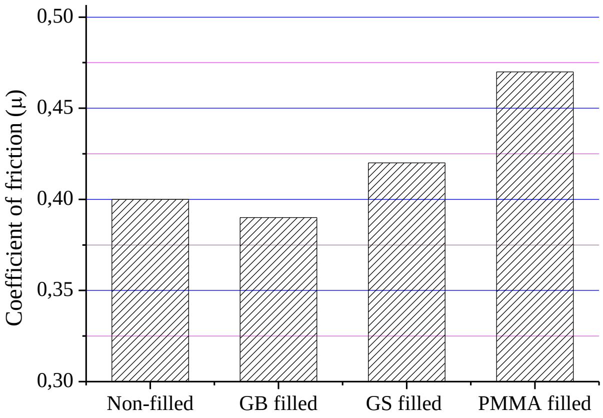

Fig. 4. The coefficient of friction values of samples.

The volume loss values of samples were calculated according to a standard test method (ASTM G99-05) by assuming that there was no significant pin wear [12]:

$$V = \frac{\pi . R . D^3}{6 . r} \tag{1}$$

Here *V* is the volume loss (mm^3), *R* is the friction radius (5 mm), *D* is the wear trace width (mm) and r is the ball radius (3 mm). Figure 5 shows volume loss values of samples. GB filled sample has the minimum volume loss value in the samples. PMMA filled sample has the most volume loss value in the samples. Shibata et al. also stated GB filled polymer composites showed low friction and low wear values [8].

The wear rate values of samples were calculated by following equation [13]:

$$k = \frac{V}{L . X} \tag{2}$$

Here *V* is the volume loss (mm^3), *L* is the load (5 N), *X* is the sliding distance (80 m) and *k* is the wear rate (mm^3/Nm).

Figure 6 shows wear rate values of samples. GB filled sample has the least wear rate value in the samples. PMMA filled sample has the most wear rate value in the samples. Tribological performance of polymeric material can be improved significantly by the incorporation of fillers.GB filled polyester composite can give higher wear resistance than non-filled polyester. The hard powders (GB) filled samples exhibited lower volume loss and lower wear rate values as compared to non-filled samples. In their study, Klaas et al. also stated that the glass beads showed the lowest wear values [14]. The glass beads filler have a good interfacial action and can enhance the anti-wear behaviors of non-filled GFRP composite. In addition to, the greater apparent effective aspect ratio of filler could benefit to the enhancement of anti-wear behaviors of GFRP composite.

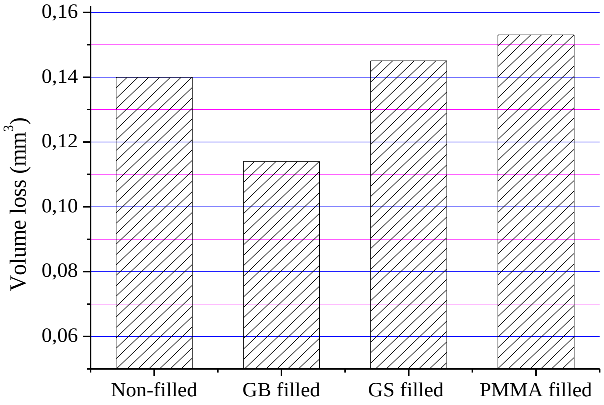

Fig. 5. The volume loss values of samples.

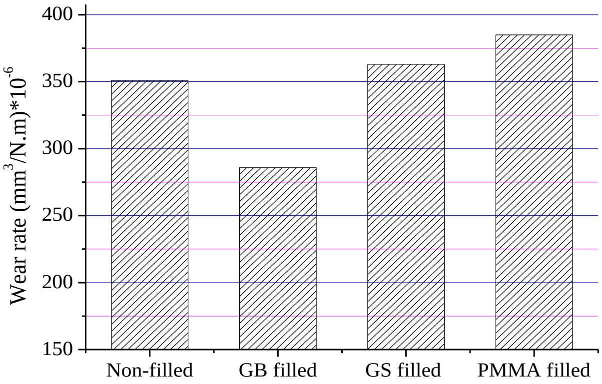

Fig. 6. The wear rate values of samples.

Table 3. The hardness of samples

Sample	Hardness (Barcol)
Non-filled	81
GB filled	81
GS filled	80
PMMA filled	83

The hardness values of samples are given in Table 3. In this table, it is seen that PMMA filled sample is the hardest material in the samples. That's why PMMA filled sample has the least wear resistance in the samples.

4. CONCLUSION

The main conclusions drawn from the present work are summarized as follows:

1. PMMA filled sample has the most coefficient of friction value (μ=0.47) in the samples. GB filled sample has least coefficient of friction values (μ=0.39) in the samples.
2. GB filled sample has the least volume loss value (V=0.114 mm^3) in the samples. PMMA filled sample has the most volume loss value (V=0.153 mm^3) in the samples.
3. GB filled sample has the least wear rate value (k=286 $mm^3/N.m*10^{-6}$) in the samples. PMMA filled sample has the most wear rate value (k=385 $mm^3/N.m*10^{-6}$) in the samples.
4. PMMA filled sample is the hardest material (83 barcol) in the samples.

Consequently, the wear resistance of the GB filled GFRP composite samples was much more than non-filled and PMMA filled GFRP composite samples.

Acknowledgement

The author wishes to thank “Sami Tongün Glass Fiber Polyester Products, Kocaeli/Turkey” for their supports of materials supply.

REFERENCES

[1] H. Pıhtılı and N.Tosun, ‘Investigation of the wear behaviour of a glass-fibre-reinforced composite and plain polyester resin’, *Composites Science and Technology*, vol. 62, pp. 367–370, 2002.

[2] F. Mata, V.N. Gaitonde, S.R. Karnik and J.P. Davim, ‘Influence of cutting conditions on machinability aspects of PEEK, PEEK CF 30 and PEEK GF 30 composites using PCD tools’, *Journal of Materials Processing Technology,* vol. 209, no. 4, pp. 1980–1987, 2009.

[3] N. Mohan, S. Natarajan and S.P. Kumaresh Babu, ‘Abrasive wear behaviour of hard powders filled glass fabric–epoxy hybrid composites’, Materials *and Design,* vol. 32, pp. 1704–1709, 2011.

[4] J. Quintelier, P. Samyn, L. De Doncker, J. Vermeulen, T. Tuzolana, L. Cardon, K. Ragaert, P. De Baets and J.Degrieck, ‘Self-lubricating and self-protecting properties of polymer composites for wear and friction applications’, *Polymer Composites*, pp. 932–940, 2009.

[5] H. Pihtili, ‘An experimental investigation of wear of glass fibre–epoxy resin and glass fibre–polyester resin composite materials’, *European Polymer Journal,* vol. 45, pp. 149–154, 2009.

[6] N. Chand, A. Naik and S. Neogi, ‘Three-body abrasive wear of short glass fibre polyester composite’, *Wear,* vol. 242, pp. 38–46, 2000.

[7] A.K. Singh, Siddharhta and Deepak, ‘Assessment of mechanical and three-body abrasive wear peculiarity of TiO_2- and ZnO-filled bi-directional E-glass fibre-based polyester composites’, *Bulletin of Material Science*, vol. 39, no. 4, pp. 971–988, 2016.

[8] K. Shibata, T. Yamaguchi and K. Hokkirigawa, ‘Tribological behavior of polyamide 66/rice bran ceramics and polyamide 66/glass bead composites’, *Wear*, vol. 317, no. 1-2, pp. 1-7, 2014.

[9] K. Soygun, G. Bolayir and A. Boztug, ‘Mechanical and thermal properties of polyamide versus reinforced PMMA denture base materials’, *The Journal of Advanced Prosthodontics*, vol. 5, pp. 153-160, 2013.

[10] E.A. Stefanescu, X. Tan, Z. Lin, N. Bowler and M. R. Kessler, ‘Multifunctional fiberglass-reinforced PMMA-BaTiO3 structural/dielectric composites’, *Polymer*, vol. 52, pp. 2016-2024, 2011.

[11] H. Zengin, J.A. Siddiqui and R.M. Ottenbrite, ‘Glass bead grafting with poly (carboxylic acid) polymers and maleic anhydride copolymers’, *Polymer for Advanced Technology*, vol. 19, pp. 105–113, 2008.

[12] C.H. Navarro, K.J. Moreno, A. Arizmendi-Morquecho, A. Chavez-Valdez and S. García-Miranda, ‘Preparation and tribological properties of chitosan / hydroxyapatite composite coatings applied on ultra-high molecular weight polyethylene substrate’, *Journal of Plastic Film and Sheeting*, vol. 28, pp. 279-297, 2012.

[13] L.D Aguilera-Camacho, C. Hernandez-Navarro, K.J. Moreno, J.S. García-Miranda and A. Arizmendi-Morquecho, ‘Improvement effects of CaO nanoparticles on tribological and microhardness properties of PMMA coating’, *Journal of Coatings Technology and Research*, vol. 12, pp. 347-355, 2015.

[14] N.V. Klaas, K. Marcusand, C. Kellock, ‘The tribological behaviour of glass filled polytetrafluoroethylene’, *Tribology International*, vol. 38, no. 9, pp. 824-833, 2005.