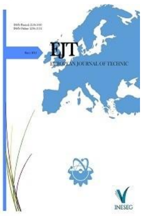
European Journal of Technique

journal homepage: https://dergipark.org.tr/en/pub/ejt

Vol.11, No.1, 2021



Effects of Sliding Distance Speed and Load on Wear and Temperature in Different Matrix and Fiber-Reinforced Composite Materials

H.Pıhtılı

Department of Mechanical Engineering, Engineering Faculty, Firat University, 23279 Elazığ, Turkey,(e-mail: hpihtili@firat.edu.tr)

ARTICLE INFO

Received: Oct., 20. 2020
Revised: Apr., 14. 2021
Accepted: Jun., 10. 2021

Keywords:
Wear
Glass Fibers
Woven Fabric Polyester Resin
Epoxy Resin
Composite Materials

Corresponding author: *H.Pıhtılı*

ISSN: *2536-5010* | e-ISSN: *2536-5134*

DOI: https://doi.org/10.17694/ejt.813718

ABSTRACT

In this study, wear behaviours of fiber-reinforced and matrix composite materials are experimentally investigated under different speeds, loads and temperature. Composite materials were made of Kevlar-epoxy resin, glass fibre-epoxy resin and glass fibre -polyester resin materials. Tests were conducted for speeds of 0,390 and 0,557 m/s , at two different loads of 5N and 10N, respectively. Wear in the experiments was determined as lost in mass. In addition, the photographs of specimens were taken under the SEM and wear behaviours on these photographs were investigated. As a result of this study, it is shown that the applied load on the specimens has more effect on the wear than that of speed. The surface temperature plays an important role in the friction and wear of polymers and increases at higher sliding speeds and loads. The temperature of the specimens increased more with the increasing sliding speed and applied load, so the wear increases more with the temperature.

1. INTRODUCTION

In industry applications, increase in using composite materials causes that it is necessary to know behaviour of working conditions, so that wear is the most important parameter and its experimental behaviour must be known. The kind of composite material used in production technology and their usage areas have been increased every day. Fiber-reinforced polymer composite, due to good combination of properties, are used particularly in automobile and airplane industries, the manufacturing of spaceship and sea vehicles. Composite materials are ideal for structural applications where high strength-to- mass ratio and specific stiffness of GFRP is not extraordinarily high. Especially woven fabrics have rather low specific strength and stiffness is required. Aircraft and spacecraft are typical mass-sensitive structures in which composite materials are cost effective. To gain full advantages of composite materials, both aircraft and spacecraft are being designed in a manner much different designing with composites is state of the art [1]. The increase in the usage of composite materials means that it is necessary to know their behaviour under working conditions. The wear resistance is an important parameter and its experimental behaviour must be known. Composite materials are being used more and more instead of steels and other metals because of their high strength at low specific mass. Besides, wider choices of materials and manufacturing of GFRP still require a lot of handworks and are rather expensive make them an ideal case for engineering applications [2, 3, 4]. On account of their good combinations of properties, fibre reinforced polymer composites are used particularly in the automotive and aircraft industries, the manufacturing of spaceships and sea vehicles [5, 6]. Nowadays, non-metal composite materials are being widely used as an alternative to steel and other materials. There are two main characteristics which make these materials attractive comparing conventional metallic designs. They are of relatively low density and they can be tailored to have stacking sequences to provide high strength and stiffness in the direction of high loadings [8].Composite materials consist of a resin and reinforcement chosen according to desired mechanical properties and the application [9, 10]. Among the fibre reinforcements, glass, carbon and aramid fibres are the most likely candidates and are widely employed. Polymer composites reinforced with these fibres are usually one to four times stronger and stiffer than their unfilled equivalents [11]. Among the resins, polyester, epoxy, phenolic and silicon resins are the most likely candidates and are widely employed.The ever-increasing demand for reliability and long life of machines are one of the main problems of contemporary engineering [12]. In industry, particularly materials working in places where wear properties are desired to be wear resisting.

For this reason, the wear resistance of the materials must be known [7]. Wear (DIN 50320) is called as occurring non-desired modifications with deviation of little pieces due to a mechanical cause or energy on surface of material [13].Many studies reported that the wear resistance with polymer sliding against steel improved when the polymers are reinforced with glass or aramid fibres. However, the behaviour is affected by factors such as the type, amount, size, shape and orientation of the fibres, the matrix composition and the test conditions such as load, speed and temperature [11, 13, and 19]. The wear resistance of materials is determined in the result of laboratory experiments. In this study, the wear behaviours of woven glass fibre, composite materials are investigated under different loads, speeds, temperature and sliding distances.

2. Experimental Procedure

In this work, composite materials were made of Kevlar-epoxy resin, glass fibre-epoxy resin and glass fibre -polyester resin material. They had a quasi-isotropic stacking sequence, 90^0, with the surface ply, which is contact with friction during experiments having a 90^0 fibre orientation direction. Wear behaviour of the glass fibre-polyester resin (provided by Fiber Cag, Turkey) and glass fibre-epoxy matrix resin (CYCOM7701) provided by TAI, Turkey are experimentally investigated. The woven glass fibre-reinforced composites made of 425 gm^{-2} and 500 gm^{-2} (yarns can be produced from a wide range of fibers and whiskers. In the case of short fibers and whiskers, the yarn must be spun (or twisted) to hold the fibers together. Continuous fibers require no spinning, but it is often advantageous to do so. Fabrics are produced from these yarns by normal weaving processes). If the fibres are not spun the fabrics are usually denser and involve quite less fibre flexure. Plain wave glass fibre-polyester matrixes contain E glass fibres of diameter 10-24 μm. Woven fabrics should be used when high shear strengths are required in the plane of the reinforcing sheet. The more unidirectional weaves generally have lower shear strengths than conventional weaves. The glass fibre composites have been reinforced with the volume of fibers $V_f = 30$ vol % and with the volume of matrix V_m=70 vol %. Matrix material used in these composites is polyester resin (Neoxil CE92). It is often desirable to add mineral filler to polyester resins. In addition to lowering the cost of resins, filler materials also improve the surface appearance, resistance to water and reduce shrinkage. Polyesters are also commonly used as matrix materials, particularly with glass fibre reinforcement. Polyester is an economic material that has high chemical resistance and resistance to environmental effects. It has high dimensional stability and low moisture absorption. Low volume-fraction glass fibre-polyester composites with a wide range of colours have been in use for a long time. The production technologies for glass and thermoset glass-polyester composites are easier and cheaper than those for other glass-resin materials [5, 6, and 15].

Glass-fibre reinforced polymer with thermoset polyester resin is an attractive material that is economically desired. Its applications at low temperatures and under service terms are easy, when this material is compared to advanced polymer composites with complex molecule structure, high strength and working under terms of difficult service [5, 6, 12]. This material is preferred due to the superiority of polymer mixed material, because it is easy to produce and at low east, more than advanced engineering applications. It is being questioned the developed and improved properties of this material in present [9]. Epoxy resins of several families are now available ranging from viscous liquids to high-melting solids. Among them, the conventional epoxy resins manufactured from epiclorohydrin and bisphenol remain the major type used. Epoxy resins are also modified with plasticizers [5, 6]. They are generally known as products used in structural component, adhesives, and protective plating due to their very good mechanical properties, chemical resistant and electrical characteristics. The shrinkage of epoxy is less than 2 % and there is no water or volatile by-products generated during curing. When these epoxy resins are reinforced with high-strengthened fiberglass, the obtained product is used in structural applications to resolve need of high hardness and lightness [9, 18].

2.1. Wear Test Details

The woven glassfiber-epoxy matrix resin, the woven glassfiber-polyester matrix resin and Kevlar-epoxy resin composite materials were provided in the dimension of 310x290x3 mm^3. The experiment specimens of size 47x27x3 mm^3 were cut from the sheets Fig.1. The wear of composite materials was performed using a block on shaft test method Fig. 2. The abrasive used at the wear of specimens is SAE 1030 (DIN 22) steel ground whose surface ground and the diameter of 15mm. The hardness and surface roughness (R_a) of the depreciator shaft are 150 HB30 and 1.25 μm, respectively. The wear tests were performed on a specially prepared experimental set-up by using a lathe. The actual loads were placed on the pan of the load arm of this apparatus. The schematic view of wear set-up is shown in Fig.2.The role of experimental conditions is very important in experimental studies.

.

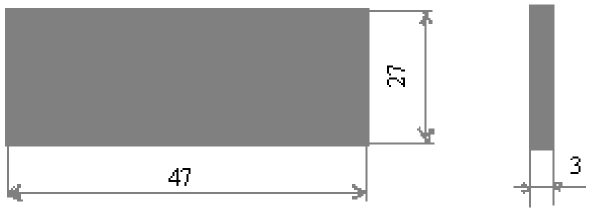


Figure 1. Dimensions of the plate used for the wear experiment

First, ambient conditions should not be changed during the experiment sets for the accuracy. The experiments were repeated till if any change of the experiment conditions had been observed.

First, ambient conditions should not be changed during the experiment sets for the accuracy. The experiments were repeated till if any change of the experiment conditions had been observed. The amount of wear will able to increase with the effect of temperature. Because it is determined that the depreciator shaft was heating in the results of a performed experiment; a new experiment was performed after the shaft was completely cooled in all experiments.

All the experiments were conducted at the room temperature (20 ^{0}C). The temperature of the specimens was measured with a Cole-Palmer H-08406-46 infrared temperature measurement device. The glassfiber-epoxy resin, glassfiber-polyester resin and the Kevlar-epoxy resin composite materials specimens were tested under the different experiment conditions. Tests were conducted for 0,390 and 0,557 m/s speeds, at two different loads of 5N and 10N. The mass losses were measured at each different sliding distances. Wear in the experiments was determined as mass loss. For each experiment, one of the specimens was used. The amount of wear was measured before the experiment and after the experiment with the apparatus of balance scales with an accuracy of 10^{-3} g.

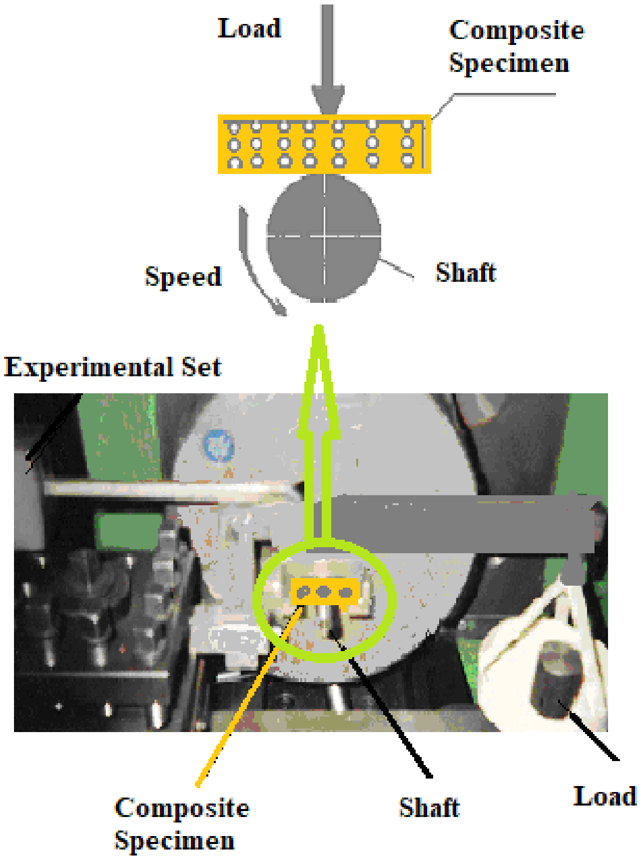


Figure 2. Photograph of the experimental setup and schematic view of a block-on-shaft wear test.

3 . The experimental results and discussion

The wear and friction behaviour of polymeric composites have to be considered as a function of load, sliding speed and distance or temperature. The surface temperature plays an important role in the friction and wear of polymers. An increase in wear intensity can occur thermal softening. Effects of the normal load and the sliding speed on the mass loss of woven glass fibre, glass fibre-epoxy resin and glass fibre-polyester resin composite specimens are shown in Figs. 3-13, respectively. The mass loss of the glass fibre-polyester resin composite specimens did not change below the sliding distance of 942m, as shown in Fig. 3.

However, the mass loss of the plain polyester resin increased after the sliding distance 942 m. This result may be explained as the increase of the temperature occurred at the experiments. The wear on the glass-fiber polyester composite decreases due to the effect of increasing temperature removal from the surface as illustrated. The epoxy-based composite exhibits lower wear loss than that of polyester-based composite [18, 20]. The mass loss is lower in glass fiber-epoxy resin composite specimens than in fiberglass-polyester resin composite under 0,390 m/s speed and 5N load according to the sliding distance in Fig. 3. SEM photograph shows the features of worn surface at 0, 39 m/s speed and 5 N load in Fig.4. The results also show that the wear did not occur in Kevlar fibre-reinforced composite specimens at 0,390 m/s speed and 5N load. From Figs. 3–5, it is seen that the wear increased with the increasing sliding distance. The mass loss of all the composite specimens generally increased with the sliding distance at the constant sliding speed 0,390 m/s when the applied load was increased from 5 to 10N (compare Fig. 3 with Fig. 5 and in Fig. 6). Because the fiberglass-epoxy resin has a low friction coefficient and high wear resistance; the mass loss of the fiberglass epoxy resin is lower than that of fiberglass-polyester composite [5, 6, 12].

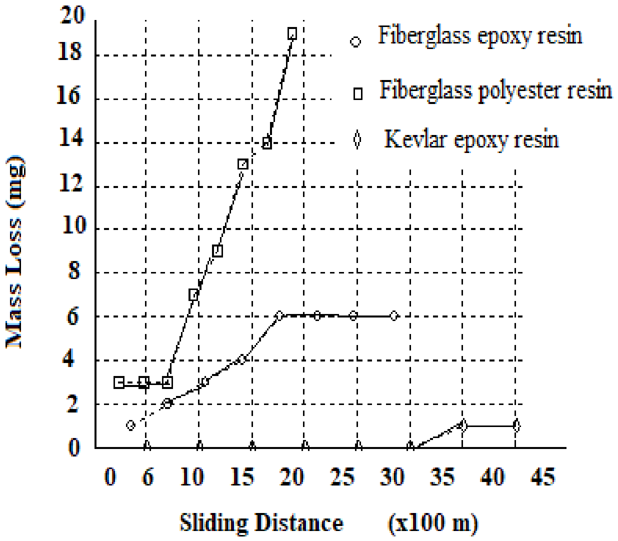


Figure 3. Variation of mass loss with respect to sliding distance at 0,390 m/s speed and 5N load.

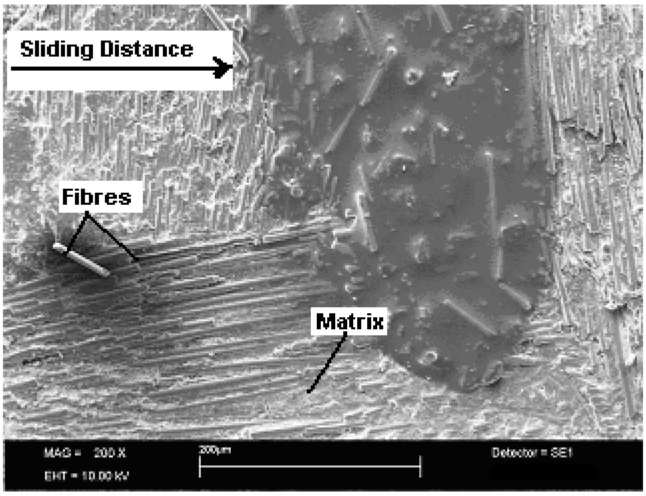


Figure 4. SEM photograph showing the worn surface of glass fiber–epoxy resin Composite at 0,390 m/s speed and 5N load.

Because of the low friction coefficient of epoxy resin, the temperature is increased. For this reason, the mass loss becomes less depending on the sliding distance as shown in Fig. 5.

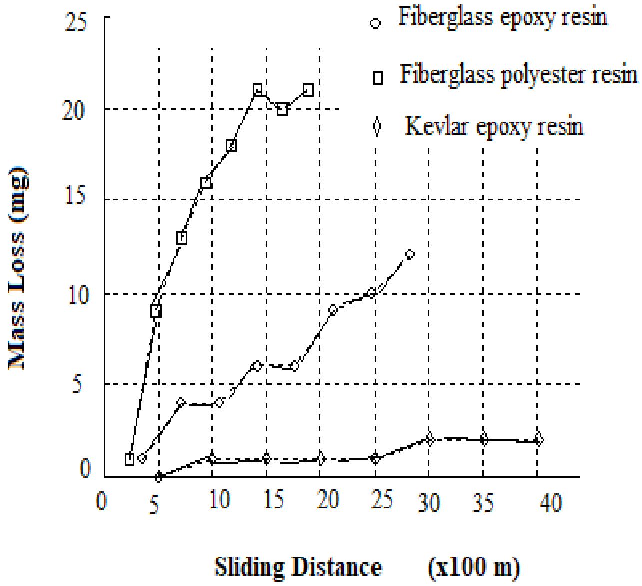


Figure 5. Variation of mass lost with respect to the sliding distance for 0,390 m/s speed and 10N load.

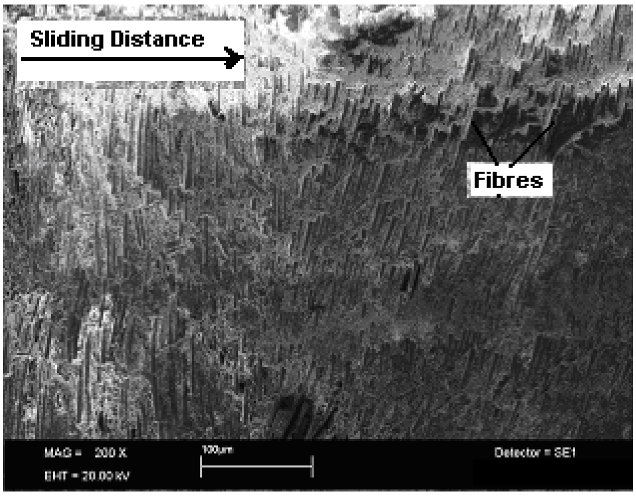


Figure 6 . SEM photograph showing the worn surface of glass fiber–epoxy resin composite at 0,390 m/s speed and 10N load.

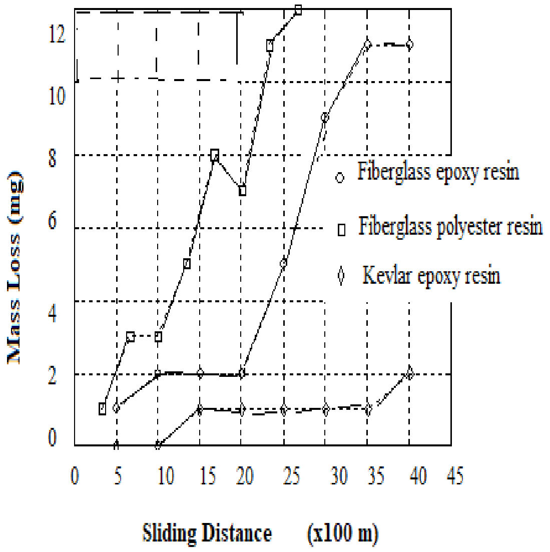


Figure 7. Variation of mass lost with respect to the sliding distance for 0,557 m/s speed and 5N load.

A little increase in temperature depends on sliding distance at 0,557 m/s speed and 5N load. The wear will occur in the polyester resin rather than the reinforcement. SEM photograph in Fig. 8. Shows the features of worn surface at 0,557 m/s speed and 5N load. As the earlier mentioned, epoxy-based composites exhibit lower wear loss than polyester-based composites. In addition, kevlar fibres usually exhibit much higher wear resistance than glass fibres [8, 14] and kevlar fibres exhibit lower friction than glass fibres. The low friction coefficient is prevented to increase of the temperature. For this reason, the mass loss of the kevlar fibre-reinforced composite material becomes less than that exhibited by the woven glass fabric-reinforced composites. The woven glass fabric-reinforced composites were subjected to a larger mass loss depending on sliding distance, when both the sliding speed and the applied load are increased as it can be seen in Fig. 8.

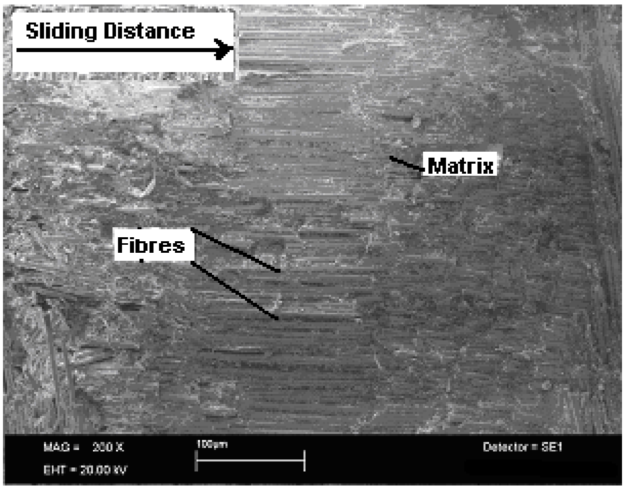


Figure 8. SEM photograph showing the worn surface of fiberglass–epoxy resin composite at 0,557 m/s speed and 5N load.

It is well-known that the surface temperature plays an important role in the friction and wear of polymers and thus it increases at higher sliding speeds and loads [5, 6, 18]. The applied load on the specimens has more effect on the wear than the sliding speed according to the data given in Figs. 3–11. SEM photographs in Figs. 4 and 6 depict the features of worn surface in sample subjected to increasing distance of sliding. In Fig. 7, the wear of matrix material due to larger sliding distance compared to Fig. 5 is noticeable comparing Fig. 9 with Fig. 10, it is possible to highlight the effect of increasing load application on the wear surface features. As seen in Fig. 13, when load is increased, causes to rise of temperature up to a point, the ends of fibers are broken due to matrix detachment. composite for all the speeds and loads according to sliding distances (Figure 3, 5, 6, 8 and 9).Glass fibre-epoxy resin composites generally showed higher resistance and minimum wear if we compare with the glass fibre-polyester matrix resin composites materials. The glass fibre-epoxy resin composites have a low friction coefficient and high wear strength, which prevents the increase of temperature. For this reason, the mass loss of glass fibre-epoxy resin composites is low depending on the sliding distance. The study also showed that higher loads and sliding velocities bring about changes in worn surface features such as interface separation, inclined fracture of fibres, loss of matrix as well as the appearance of debris with the two different. The wear occurs in the matrix rather than the reinforcement.

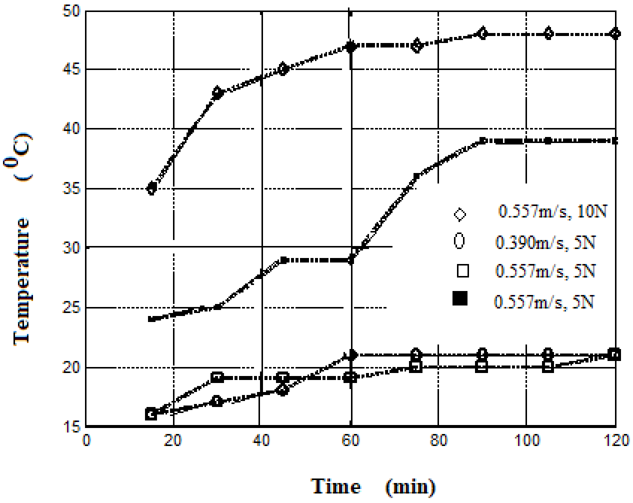


Figure 9. Effect of speed and load on temperature (20 ^{0}C) and time of fiberglass–polyester resin composite.

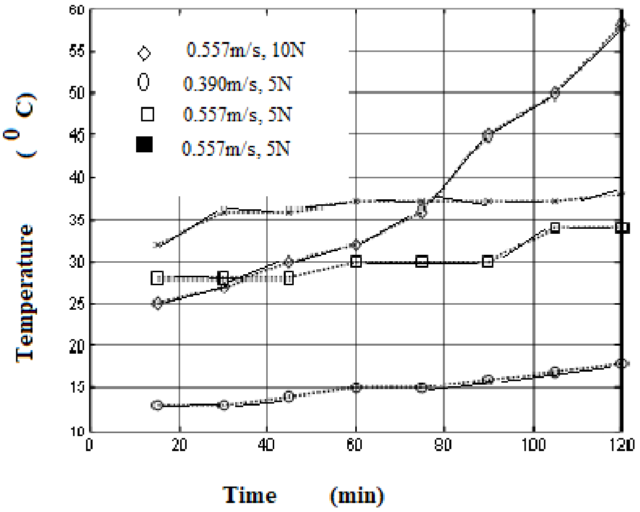


Figure 10. Effect of speed and load on temperature(20 ^{0}C) of fiberglass–epoxy resin composite.

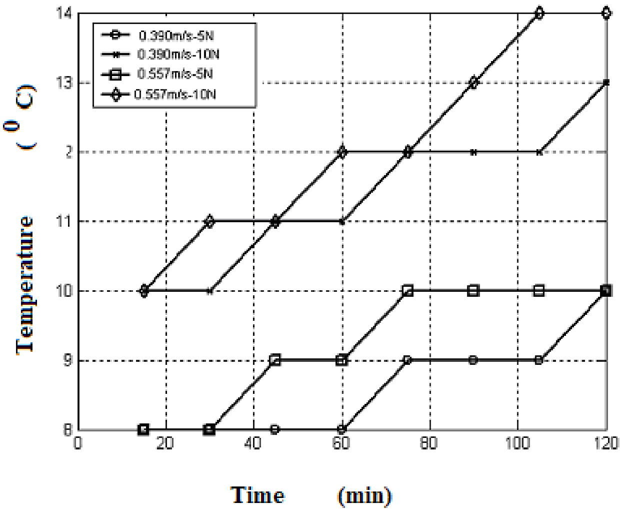


Figure 11. Effect of speed and load on temperature (20 ^{0}C) of kevlar-epoxy resin composite.

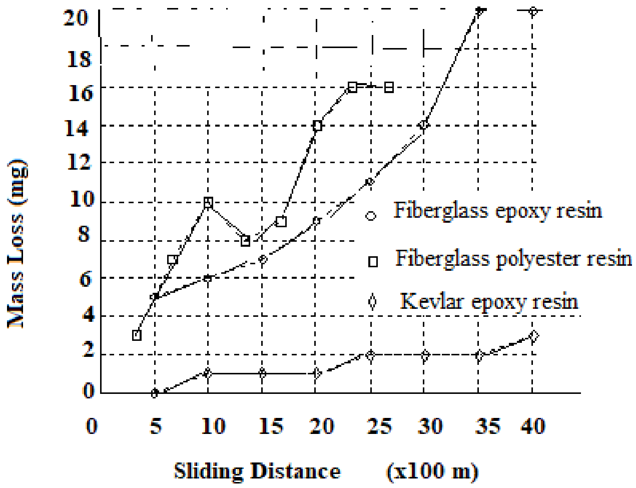


Figure 12. Variation of mass loss with respect to the sliding velocity for 0,557 m/s speed and 10N load.

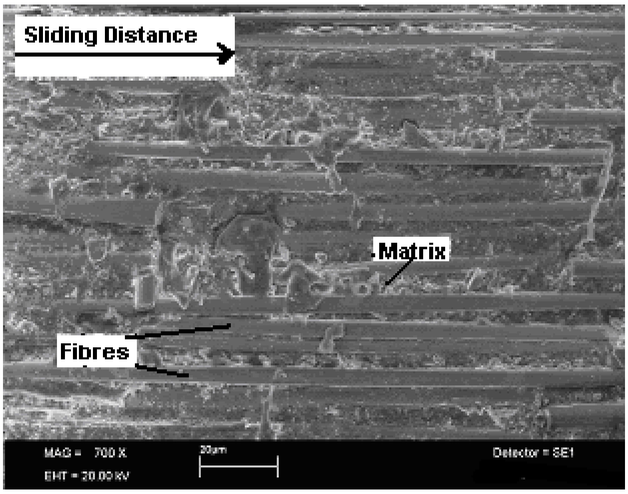


Figure 13. SEM photograph showing the worn surface of glass fibre–epoxy resin composite at 0,557 m/s speed and 10N load.

3 . Conclusion

The mass loss of the woven glass fibre-epoxy resin composite increases with increasing of load and speed. Because the temperature raised with increasing of load and speed. The mass loss of all composite specimens generally increased with the sliding distance at the constant sliding speed of 0, 390m/s when the applied load was increased from 5N to 10N (compare Fig. 3 with Fig. 5, and Fig. 6).

The wear in the woven glass fibre-epoxy resin composite specimens is lower than the woven glass fibre-polyester resin Therefore, the wear in the woven 425 gm^{-2} glass fabric-reinforced composite is lower than the woven 500 gm^{-2} glass fabric-reinforced composite keeping all test parameters constant. Due to the kevlar fibres having a low friction coefficient and high wear strength, and epoxy-based composite exhibit lower wear loss than polyester-based composite, the wear of the kevlar fibre-reinforced composite is lower than the woven glass fabric-reinforced composites.

REFERENCES

[1] Vinson, J.R., Chou, T., Composite Materials and their use in structures, London, (1975).

[2] Kishore, Sampathkumaran P., Seetharamu S., Murali A. and Kumar R.K. Journal of Reinforced Plastics and Composites.; 18(1):55–62,(1999).

[3] Kishore, Sampathkumaran P., Seetharamu S., Vynatheya S., Murali A. and Kumar R.K., SEM Observations of The Effects Of Velocity and Load on The Sliding Wear Characteristics of Glass Fabric–Epoxy Composites with Different Fillers", Wear,237: 20–27, (2000).

[4] A.A. Collyer, "Rubber Toughened Engineering Materials", Chapman & Hall, London, (1994).

[5] Pihtili, H., Tosun,N., "Effect of load and speed on the wear behaviour of woven glass fabrics and aramid fibre-reinforced composites" , Wear 252 , 979 -984, (2002).

[6] Pihtili, H., Tosun,N "Investigation of the wear behaviour of a glass-.fibre-reinforced composite and polyester resin Composites", Science and Technology 62; 367–370,(2002).

[7] N.S. El-Tayep, R.M. Gadelrap, "Friction and wear properties of E-glass fiber reinforced epoksi composites under different sliding contact conditions", Wear 192,; 112-117,(1996).

[8] N. Chand, A. Naik, S. Neogi "Three-body abrasive wear of short glass fibre polyester composite", Wear 242; 38–46,(2000).

[9] T. Kunishima, T. Kurokawa, H. Arai, V. Fridrici, P. Kapsa, Reactive extrusion mechanism, mechanical and tribological behavior of fiber reinforced polyamide 66 with added carbodiimide Mater. Des., 188 Article 108447, (2020).

[10]] S.N. Kukureka, C.J. Hooke, M. Rao, P. Liao, Y.K. Chen, "The effect of fibre reinforcement on the friction and wear af polyamide 66 under dry rolling–sliding contact", Tribol. Int. 32,; 107–116,(1999).

[11] V.K. Srivastava, J.P. Pathak, "Friction and wear properties of bushing bearing of graphite filled short glass fibre composite in dry sliding", Wear 197 ,; 145–150,(1996).

[12] ASM Handbook, ASM International. Materials Park. USA. 1992.

[13] R.Ramesh, Kishore, Rao R.M.V.G.K, "Dry sliding wear studies in glass fiber reinforced epoxy composites", Wear, 89: 131, (1983).

[14] Bolvari AE, Gleen SB. Eng Plast, 9:205 –15. (1996).

[15] T. Kunishima, S. Nagai, T. Kurokawa, J. Galipaud, G. Guillonneau, G. Bouvard, J.-Ch Abry, C. Minfray, V. Fridrici, Kapsa effects of temperature and addition of zinc carboxylate to grease on the tribological properties of PA66 in contact with carbon steel Tribol. Int. p. 106578, (2020).

[16] D. Zhao, H. Hamada, Y. YangInfluence of polyurethane dispersion as surface treatment on mechanical, thermal and dynamic mechanical properties of laminated woven carbon-fiber-reinforced polyamide 6 composites Compos. B Eng., 160 pp. 535-545,(2019).

[17] T. Kunishima, K. Miyake, T. Kurokawa, H., Arai Clarification of tribological behavior on tooth surface of resin worm gear for electric power steering, JTEKT Eng. J. English Edition, 1013E pp. 27-33, (2016).

[18] B.Vishwanath, A.P. Verma, C.V.S. (Kameswara Rao, Composite Sci. Technol. 44 (1),77–86,(1992).

[19] J. Chen, H. Xu, C. Liu, L. Mi, CShenThe effect of double grafted interface layer on the properties of carbon fiber reinforced polyamide 66 composites Compos. Sci. Technol., 168 pp. 20-27,(2018).

[20]] D.W. Gebretsadik, J. Hardell, B. PrakashFriction and wear characteristics of PA 66 polymer composite/316L stainless steel tribopair in aqueous solution with different salt levels Tribol. Int., 141, Article 105917, ,(2020).

[21] M.T. Lates, R. Velicu, C.C. Gavrila Temperature, pressure, and velocity influence on the ribological properties of PA66 and PA46 Polyamides,Materials, 12 (20) p. 3452. (2019).

[22] Y.K. Chen, O.P. Modi, A.S. Mhay, A. Chrysanthou, J.M. O'Sullivan, (2003). The effect of different metallic counterface materials and different surface treatments on the wear and friction of polyamide 66 and its composite in rolling-sliding contact Wear, 255, pp. 714-721.

[23] T. Kunishima, Y. Nagai, T. Kurokawa, G. Bouvard, J.- C. Abry, V. Fridrici, P. Kapsa, Tribological behavior of glass fiber reinforced-PA66 in contact with carbon steel under high contact pressure, sliding and grease lubricated conditions Wear. (2020).

[24] N.G. Karsli, T. Yilmaz, O. Gul, Effects of coupling agent addition on the adhesive wear, frictional and thermal properties of glass fiber-reinforced polyamide 6,6 composites Polym. Bull., 75 pp. 4429-4444. (2018).

[25] N.G. Karsli, S. Demirkol, T. Yilmaz, Thermal aging and reinforcement type effects on the tribological, thermal, thermomechanical, physical and morphological properties of poly (ether ether ketone) composites,Compos. Part B, 88 pp. 253-263 (2016).

BIOGRAPHIES

Haşim Pıhtılı was graduated from Firat University the department of Mechanical Engineering in 1986. Then he started his master science study and became research assistant in the same university. He completed his master study in 1988. He was completed PhD study in 1991 and promoted to assistant professor in 1993. He has been Associate Professor in 2015. He has taught the lectures of machine elements, composite materials and laboratory courses related to construction and manufacturing since 1988. He has numerous publications in national and international journals. Particularly, they are mainly about wear, composite materials and construction of machines. He has a chapter in the book namely Woven fabric engineering. He has also edited the book 'Tribology in Engineering'. He is still reviewer in various journals, a member of Turkish Composites Manufacturers Association (TCMA) and he has five patent at the same time.