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Investigation of Wear and Surface Roughness of Different Woven Glass Fabrics and Aramid Fibre-Reinforced Composites

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1. Introduction

Composite Materials with Plastic Matrix has attained a broad utilization area due to their several qualities such as lightness, rigidity, heat resistance, high endurance limit, good resistance to wear in space and aircraft industry, automobile industry (piston, parts of engine, fan and compressor), sports and sea materials. Although manufacturing industry has developed good methods of manufacturing with modern machining, the traditional hole drilling method is still the most commonly used operation process due to its being economical and simple applicability. Drilling process is quite commonly used in defense, aviation and automobile industries [1]. In the production industry, non-metal composite materials are just beginning to be used alternatively instead of steel and other metals. Polymers and their composites are being increasingly employed in view of their high strengths and low densities. 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 [2.3.4–5]. The wear resistance of materials is determined by experiments that carefully performed in the laboratory.

Drilling process is quite commonly used in defence, aviation and automobile industries. When studies regarding processing composites are examined, we encounter commenly the composites with metal matrixes. In general in drilling tests made on metal matrix composites (MMC), it is seen that team wear is more and surface roughness is weak when classical high speed steel drills are used [6].

In this study, the effects of progress speed, rotation number, drill type and drill diameter on surface roughness of work sample are investigated while composite material is being machined by drilling. Besides, the wear behaviour of two woven glass fabric, namely the 300 and 500 grades, as well as aramid fibre-reinforced composite materials are investigated under different loads, speeds and sliding distances.

HSS, TIN and Carbide drills with 5, 10 and 15mm diameter were used in drilling processes. Experiments were performed with dry drilling by using values of cutting speeds of 125, 250 and 315 rpm and progresses of 0.056, 0.112 and 0.16 mm/rev.

2. Materials and specimens

In this study, woven glass fabric-reinforced composites, made of 300 and 500 gm^{-2} plain weave glass fabric, contain E glass fibres of diameter 10–24 µm were used. The woven glass fabrics are woven in two perpendicular directions. The woven glass fabrics composites consist of fibre, V_f = 30 vol.%, and matrix, V_m = 70 vol.%. Polyester resin was used as the matrix material for both composites. Another used specimen was the aramid fibre-reinforced composite. It has aramid fibres with a diameter of 10–24 µm. The aramid fibre-reinforced composite consists of fibre, V_f = 60 vol.% and matrix V_m = 40 vol.%. Epoxy resin was used as matrix material. The aramid fibre reinforced composite has been made by using filament winding process. There are three winds in this composite. The wind angle is equal to 45^o. This method produces very strong composites; therefore extremely large cylindrical and spherical vessels can be built [7]. Automotive drive shafts, helicopter blades, oxygen tanks are among the applications of filament winding [8]. All composite specimens were cut in size of 47mm × 27mm for wear tests. The woven glass fabrics and aramid fibre-reinforced composites have 4 and 1.5mm thickness, respectively.

3. Wear tests

The wear tests were performed by using a block-on-shaft test method (Fig. 1). 15mm diameter ground shaft, SAE 1030 (DIN 22) steel, was used as the counterbody. The hardness and surface roughness (*R*a) of the shaft were 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. 1. All the experiments were conducted at room temperature. The temperature of the specimens was measured with a Cole-Palmer H–08406–46 infrared temperature measurement device. The woven 300 and 500 gm^{-2} glass fabrics and the aramid fibre-reinforced composite materials specimens were tested under different experimental conditions. Tests were conducted for speeds of 500 and 710 rpm and two different loads of 500 and 1000 g. Wear rate was determined by noting the weight loss (to 10^{-3} g) that was measured after the different sliding distances. One specimen was used for each experiment. The microstructures of the worn surfaces were examined by using a scanning electron microscope (SEM).

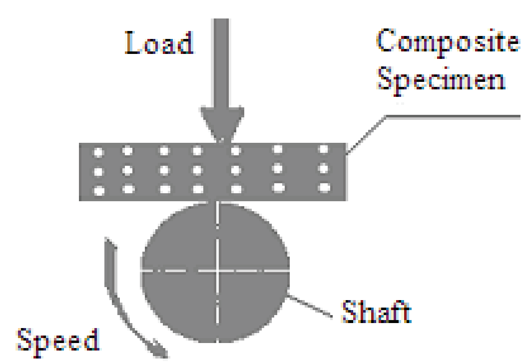

Fig. 1. Schematic showing a block-on-shaft wear test.

4. Experimental results and discussion

The effects of applied load and sliding speed on the weight loss of woven 300 and 500 glass fabrics and aramid fibre-reinforced composite specimens are shown in Figs. 2–3, respectively. The weight loss of the woven 300 glass fabric-reinforced composite specimens is lower than that exhibited by the woven 500 glass fabric-reinforced composite under the condition of 500 rpm speed and 500 g load (Fig. 2).

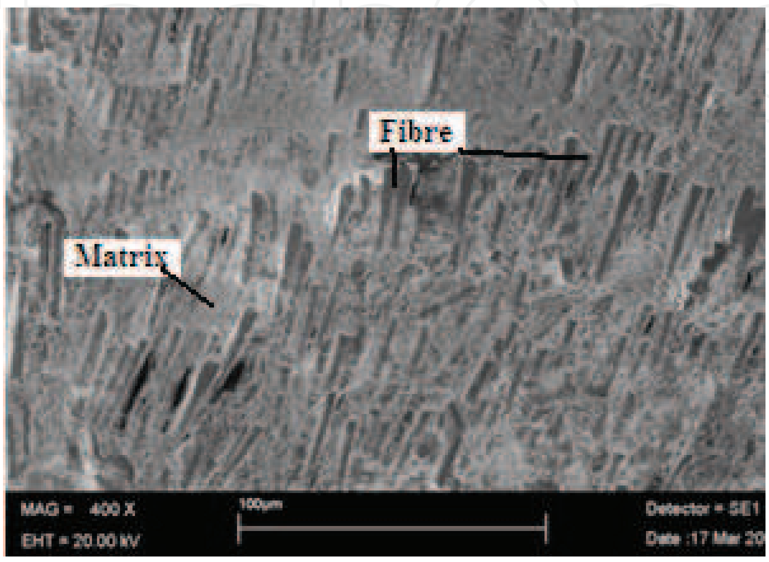

Fig. 2. SEM photograph showing the worn surface of the woven 500 glass fabric composite at 500 rpm speed and 500 g load.

The amount of matrix mass between fabrics in the woven 500 glass fabric-reinforced composite is more than that in woven 300 glass fabric-reinforced composite. For this reason, the reinforcement weight loss was very small, and weight loss was observed mainly as matrix loss. Epoxy-based composite exhibit lower wear loss than polyester-based composite [4,9]. The results also show that the wear did not occur in aramid fibre-reinforced composite specimens at 500 rpm speed and 500 g load, as shown in Fig. 2. Frequently, 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 due to thermal softening. A low thickness of the softening layer normally results in low wear intensity [4]. From Figs. 2–3, it is seen that the wear increased with the increasing sliding distance. The weight loss of all the composite specimens generally increased depending on the sliding distance at the constant sliding speed 500 rpm when the applied load was increased from 500 to 1000 g (compare Fig. 3 with Fig. 2). The thickness of the softening polyester matrix layer on the specimen surface has increased proportionally with the temperature, so this softening layer has been detached from the surface of the specimens. The wear increased with an enhanced load, due to thermal softening [4]. As the earlier mentioned, epoxy-based composites exhibit lower wear loss than polyester-based composites.

In addition, aramid fibres usually exhibit much higher wear resistance than glass fibres [4,10] and aramid fibres exhibit lower friction than glass fibres. The low friction coefficient is prevented by the temperature increase. For this reason, the weight loss of the aramid fibre reinforced composite material is lower than that exhibited by the woven glass fabric-reinforced composites. The weight loss of the woven glass fabrics and the aramid fibre reinforced composites increased by a small amount at the constant applied load (500 g) when the sliding speed was increased from 500 to 710 rpm (compare Fig. 4 with Fig. 2). The surface temperature is normally not independent of sliding speed [4]. The applied load on the specimens has more effect on the wear than the sliding speed according to the datas given in Figs. 2–4. The woven glass fabric-reinforced composites was subjected to a larger weight loss depending on sliding distance, when both the sliding speed and the applied load are increased together (Fig. 4). The surface temperature plays an important role in the friction and wear of polymers and increases at higher sliding speeds and loads [4]. The weight loss of the aramid fibre-reinforced composite had no change, as shown in Fig. 4.

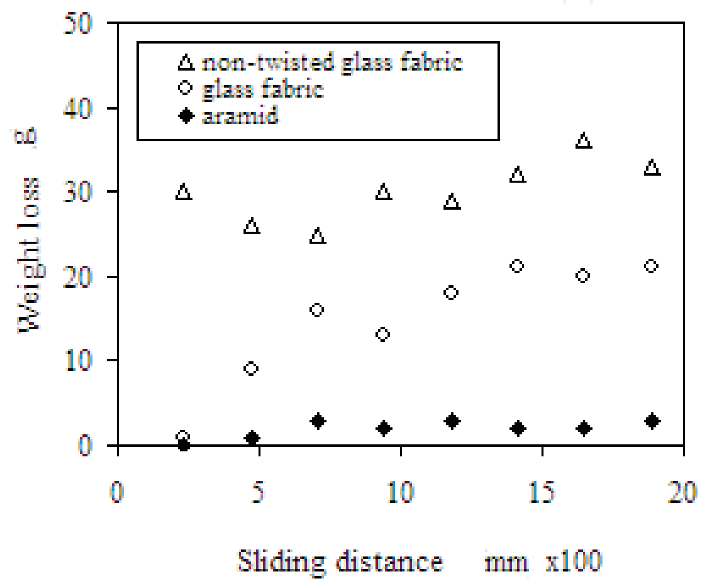

Fig. 3. Variation of weight lost with the sliding distances for 500 rpm speed and 1000 g load.

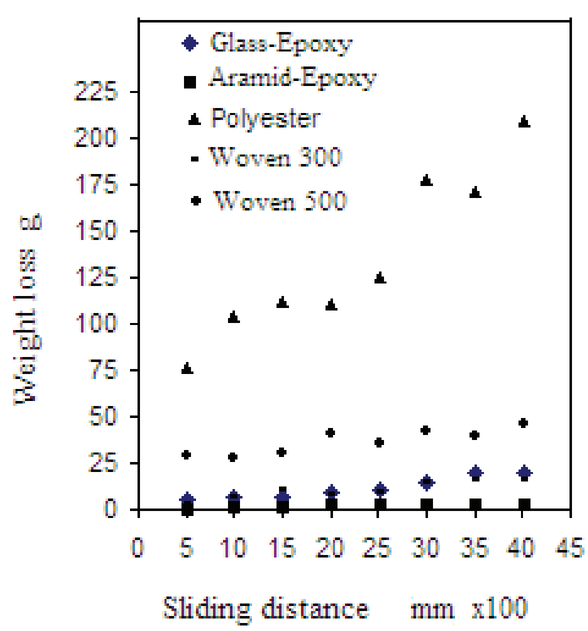

Fig. 4. Variation of weight lost with the sliding distances for 710 rpm speed and 1000 g load.

5. Drilling processes

In order to attain optimum results in drilling process, drilling length was chosed to be 15mm for the purpose of meeting the condition that drilling length should be three times or less than three times the hole diameter. Cooling liquid wasn't used in order to decrease possible heat shock in cutting tool during the experiment [11]. The experiments were done on the radial drill bench with a brand mane of Stanke Import with a progress interval of 0.056 mm/rev and 2, 5 mm/rev working between 20 and 2000 rpm. In drilling process, the effects of progress speed and number of rotations, drill type and drill peak angle, which are among the cutting parameters, on micro structure and surface roughness of work sample were investigated. In the experiments made, plastic matrixed composites manufactured in different ways were used. Some of the materials were supplied from TAI as semi-finished product. Various processes have been applied to these materials in order to use them in the experiments as products. Some other materials that were used in experiments by from (TEMSAN Turkish Elektromecanic Industry) as product. The composite materials used are shown in Table 1.

ISOVAL11- B	Epoxy / E-glass fiber	0.2 g/cm^3	3.5 mm
ISOVAL11- C	Epoxy / E-glass fiber	0.2 g/cm^3	5 mm
ISOVAL11- D	Epoxy / E-glass fiber	0.2 g/cm^3	7 mm
ISOVAL11- E	Epoxy / E-glass fiber	0.2 g/cm^3	10 mm
ISOVAL11- F	Epoxy / E-glass fiber	0.2 g/cm^3	14 mm

Table 1. The Composite Materials used in Experiments

5.1 ISOVAL11 composites

Final product with ISOVAL11 (Seen in Figure 5) series type and manufactured by TEMSAN has 0.2 g/cm^3 texture density. In Figure 6 the change in ISOVAL11 Epoxy/E-glass fiber composite and the average surface roughness is given for different drill materials. The biggest Ra value is found out for HSS drill material. In Figure 7 change in drill material

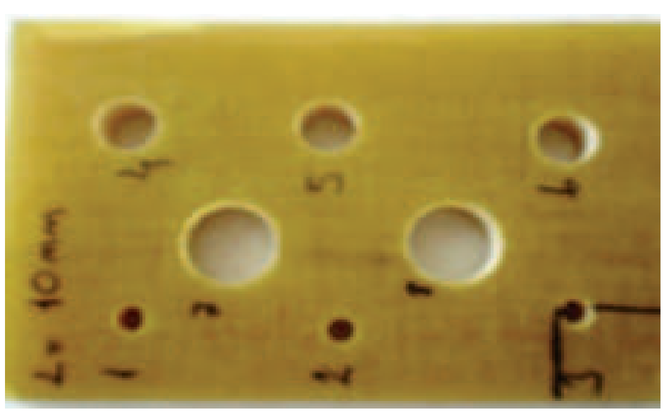

Fig. 5. ISOVAL 11 Composite materials used in experiments.

and the average surface roughness is given for ISOVAL11 Epoxy/E-glass fiber composite for different progress, rotation and drill diameters. In drills made at the same rotation and progress more sensitive surface is obtained in case Carbide drill is used and the same condition is applied for drills with 10 mm and 15 mm diameters. There is no heating on the cutting tool where swarfs extracted occures as dust. It is seen that Ry value for the holes with 15 mm diameter is lower than the other. As material thickness increases, the linearity of the results are observed and the surface roughness is measured accurately.

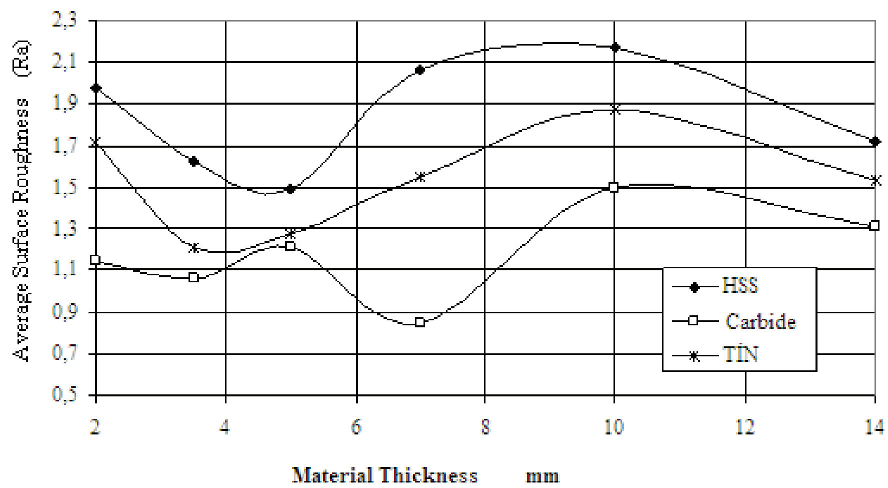

Fig. 6. The change in average surface roughness and ISOVAL11 Epoxy/E-glass fiber composite thickness. (s=0.112 mm/rot, n=250 d/min, d=10 mm).

In Figure 8 the SEM photos of middle point of hole section for ISOVAL11 Epoxy/E-glass composite drilled with HSS drill are shown. In these photos, the material texture denstity is 0.2 g/cm³ and composite thickness is 5 mm, s=0.16 mm/rot, n=315 d/min, d=15 mm. In Kevlar materials, it is seen that the surface roughness is good in middle layers and roughness decreases in materials based on the texture condition. As material thickness increases extracting the swarf out during drilling become harder. As no cooling liquid is used during experimental studies, some heating occur on the cutting tool. Moreover as the material gets thicker it has difficulty in cutting the matrix material due to the fact that cutting tool is plastered over this region as matrix material per unit volıume increases and it is observed that heating occurs more in this region. The increased progress speeds and increased surface roughness values appear also as indicator of changes in texture condition of the material.

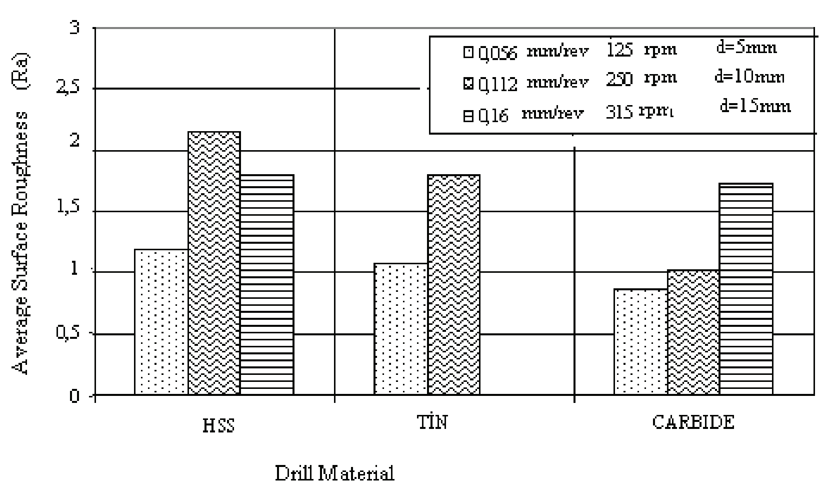

Fig. 7. The change in ISOVAL11 Epoxy/E-glass fiber composite and the average surface roughness (Texture density=0.2 g/cm³, Composite material thickness=3.5 mm).

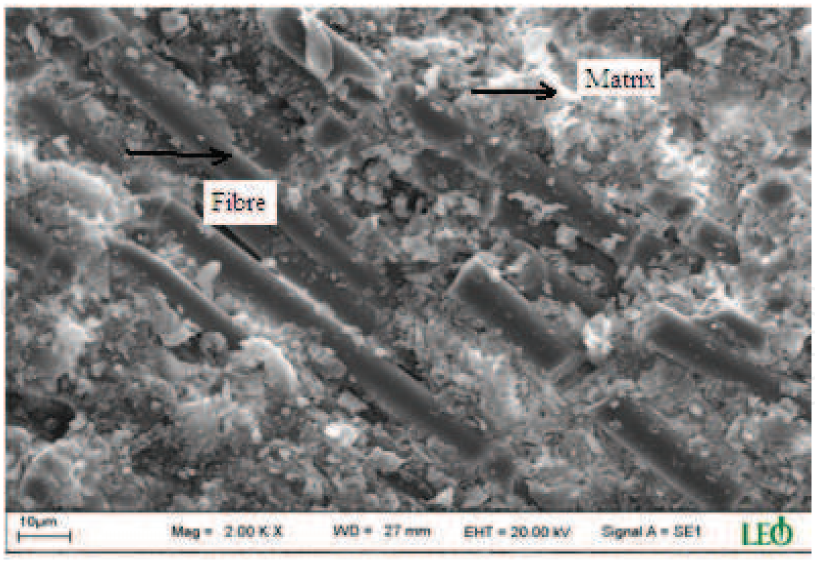

Fig. 8. 2000 times enlarged SEM photo of middlepoint of hole section for ISOVAL11 Epoxy/E-glass composite drilled with HSS drill (Texture density=0.2 g/cm^3, composite material thickness=5 mm, s=0.16 mm/rot, n=315 d/min, d=15 mm).

6. Conclusion

An experimental study of the wear behaviour of woven glass fabric and aramid fibre reinforced composites at various sliding speed, applied load and sliding distance reveals the following characteristics.

Wear of the composites depends on the experimental test parameters, such as applied load, sliding distance and speed. The applied load on the specimens has more effect on the wear than the sliding speed. The amount of matrix between fabrics in the woven 500 glass fabric-reinforced composite is more than in the woven 300 glass fabric. The wear occurs in the matrix rather than the reinforcement. Therefore, the wear in the woven 300 glass fabric-reinforced composite is lower than the woven 500 glass fabric-reinforced composite keeping all test parameters constant. Due to the aramid 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 aramid fibre-reinforced composite is lower than the woven glass fabric-reinforced composites.

The surface roughness of the composite material is investigated experimentally depending on the effect of drill type, drill diameter, number of rotation and progress speed on machinability of different composite materials in drilling.

Since no cooling liquid is used, as a result of the heating occured around the hole matrix material gets softer. Due to this, in drilling processes with all drills there is matrix concentration on the edges of hole surfaces. Sudden ruptures occur between the textures on composite materials as progress speed increases and the value of surface roughness is seen to increase in all study in general.

Considering the value of surfaceroughness depending on the number of rotation, in all drilling processes made with drills it is observed that the value of surface roughness increases as the number of rotation increases. As material thickness increases in general, the surface roughness increases; naturally drilling becomes difficult and tool heat increases as well. It was previously stated that when an investigation is made among the materials, the rupture endurance of material with Kevlar support is higher than that of fiber glass material. Due to this it is seen that drilling Kevlar supported material is more difficult. Considering all results obtained as a result of the drilling processes; it is found out that using Carbide drills as the most suitable drill type in drilling operations would create better results. Besides this, considering the cost, as the price of Carbide drills is twice as expensive as TIN covered drills which have a similar performance as Carbide drills, it can be reccommendable that TIN covered drills to be used.

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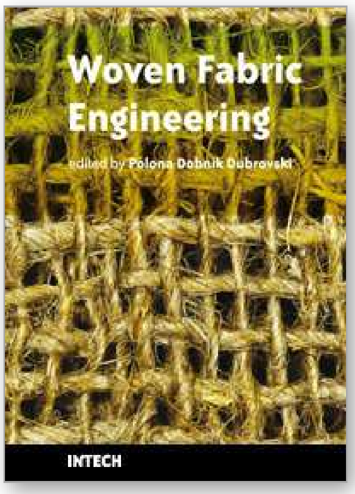

Woven Fabric Engineering
Edited by Polona Dobnik Dubrovski

ISBN 978-953-307-194-7
Hard cover, 414 pages
Publisher Sciyo
Published online 18, August, 2010
Published in print edition August, 2010

The main goal in preparing this book was to publish contemporary concepts, new discoveries and innovative ideas in the field of woven fabric engineering, predominantly for the technical applications, as well as in the field of production engineering and to stress some problems connected with the use of woven fabrics in composites. The advantage of the book Woven Fabric Engineering is its open access fully searchable by anyone anywhere, and in this way it provides the forum for dissemination and exchange of the latest scientific information on theoretical as well as applied areas of knowledge in the field of woven fabric engineering. It is strongly recommended for all those who are connected with woven fabrics, for industrial engineers, researchers and graduate students.