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Effect of SiC Particulate on Glass Fibers Reinforced Polymer Composites in Erosive Wear Environment

Abstract- *In this study the physical property, mechanical properties and erosion wear of pure epoxy and hybrid composites were studied. Composites were prepared and investigated by Hand lay-up molding. Pure epoxy and hybrid compositions were prepared, 4% and 8% volume fractions of glass fibers as reinforcement and 4% and 8% of SiC as filler particles. The investigated physical property is density while the mechanical property was hardness. Solid particles erosion wear tests are also carried out. The experimental results showed that increased volume fraction of glass fibers to (8%) led to increase the (density). The maximum density is equal (1.661gm/cm^3). Hybrid composite with (Epoxy +8%GF+8%SiC) has the maximum hardness of (82) shore D. The particle-contained water jet type experimental erosion test results that the reinforcement volume fraction as well as particles distribution and bonding has considerable effect on the wear of epoxy composites. It was found that the better resistance was for hybrid composites (Epoxy+8%GF+4%SiC) at angle 30°, erodent size 800 µm, and time 10 hour.*

Keywords- *Epoxy, Glass fibers, Hybrid composites, mechanical properties.*

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1. Introduction

Hybrid composites more sophisticated compared with conventional composites. Hybrids can have more than one phase of reinforcement, one or multiple reinforcements and have flexibility compared to others. Mechanical properties varied by changing volume ratio and stacking sequence of different plies [1]. Particles of solid erosion are one of the types of erosion that has caused the damage with the gradual loss of native materials because of the mechanical interaction between the surface and solid particles [2]. Patnaik et al. [٣] had studied Stripping in particles for a multi component hybrid composite consisting of polyester, glass fibers and alumina particles (average size 50 µm). Three different compositions for overlapping (0wt%, 10wt% and 20wt% of alumina filling).The design of experiments approach using Taguchi's orthogonal arrays has been used with impingement angle of (45^o, 60^o, and 90^o). Satapathy et al. [4] have studied the effect of three different fillings namely fly ash, alumina (Al_2O_3) and silicon carbide (SiC) on the erosion characteristics of glass polyester composites. Orthogonal arrays are used with impingement angles of (45^o, 60^o, and 90). Hybrids have good applications in the environment Al_2O_3 has been found to be the filler causing the maximum enhancement in the erosion resistance of the composite. The wear rates increase of fly ash and SiC filled composites are relatively higher than that of alumina filled counterpart under similar test conditions [4]. The objective of this research is to Prepare composites of Epoxy reinforced with glass fibers and silicon carbide (SiC) particles and Study Effect of Erosion Wear rate & mechanical property of Hardness (Shore D) and physical property Density tests of the prepared composites.

2. Experimental Work

I. Materials Used

The use of fiber glass mat (GF) in the preparation of samples supplied from the Tenax company_ England, Table 1 show typical properties of fibers glass. The epoxy resin used has the number 105 as a specification, manufactured by Ayla Construction Chemicals under license from DCP, England, with a density 1.4 g/cm^3. Table 2 show typical properties of epoxy resin [5]. Silicon carbide (SiC) is a ceramic material particulates are used as reinforcement material. Type silicon carbide is F320. Silicon carbide density is between 1, 29-1, 35 g/cm3 Surface chemical values are given in Table 3.

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II. Preparation of Composites

The hybrid composites samples are prepared from Epoxy resin (matrix material) reinforced with Glass fibers of (4% and 8%) volume fraction, and particles of silicon carbide powder (SiC) of (4% and 8%) volume fraction. The sample preparation method used in this research is the Hand lay-Up Molding. The volume fraction of the components is calculated based on the following relations [6].

$$\upsilon f = \frac{\text{mf}}{\rho\text{f}} \quad (1)$$

$$V_f = \frac{\upsilon_f}{\upsilon_c} \quad (2)$$

$$\upsilon_m = \frac{m_m}{\rho_m} \quad (3)$$

$$V_m = \frac{\upsilon_m}{\upsilon_c} \quad (4)$$

Where

m_f, m_m: Mass of fiber and matrix materials respectively. (gm)

v_c, v_m v_f: Volume of (composite, matrix and fiber) materials respectively,(cm^3)

ρ_f ,ρ_m: Density of Fiber and matrix materials respectively, (gm / cm^3).

V_f ,Vm: Volume fraction of fibers and matrix materials respectively.

3. Mechanical Test

I. *Hardness Test (Shore D)*

This test is performed by using hardness (Shore D) and according to (ASTM DI-2242) standard. Samples have been cut into a diameter of (40mm) and a thickness of (5mm). Figure 1 shows standard specimens for this test [7]. For each specimen five hardness measurements were taken and the average hardness is calculated.

4. Physical tests

I. Density Measurements

This test is performed according to (ASTM C 373) standard. The true density (ρ_t) is calculated from the method of immersion in water (Archimedes base) using the following relationship [8]. Figure ٢, the prepared specimens.

$$\rho t = \frac{\text{Wd}}{\text{Ws}-\text{Wn}} * \text{D} \quad (5)$$

Where

ρ_t : true density (gm/cm^3).

D: density of distilled water (1 gm/cm3).

W_d : weight of dry sample (gm).

W_n : weight of the sample when submerged with water (gm).

W_s : weight of the sample after saturation in water (gm).

Table 1: Typical properties of fibers glass type used in the search by the manufacture edifications

Fibers Glass	Young's modulus (GPa)	Tensile strength(MPa)	Elongation (%)	Density (gm/cm^3)
	72	3450	4.3	2.58

Table 2: Typical properties of epoxy resin [5]

Epoxy resin(EP)	Density (gm/cm^3)	Tensile modulus (GPa)	Tensile strength (MPa)	Flexural strength (MPa)
	1.4	2.41	24-90	34-200

Table 3: Typical properties of fibers glass type used in the search by the manufacture edifications

Product	%Sic	% Free C	%Si	$\%SiO_2$	$\%Fe_2O_3$
	99.50	0.10	0.10	0.10	0.05

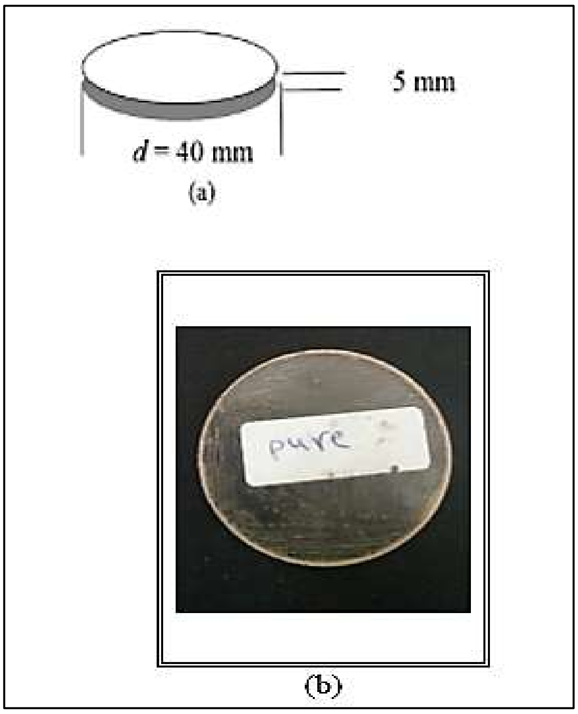

Figure 1: (a) Hardness (shore D) standard specimens [7] (b) Experimental test specimens

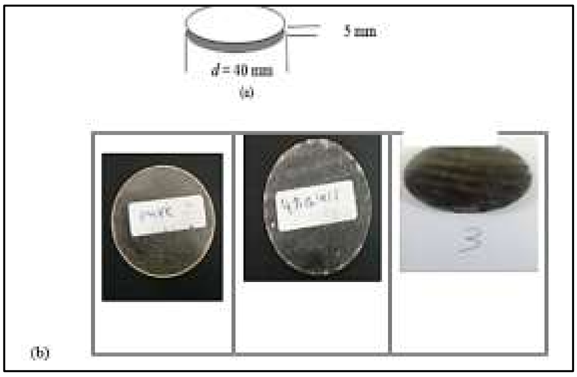

Figure 2: (a) True density standard specimens [8], (b) Experimental test specimens

5. Erosion Wear

This test is performed according to (ASTM G76) at room temperature. The device used was locally manufactured. A plastic (Perspex) tank is used as a chamber. The Plastic acrylic tank has a dimension of (40) cm in length, (20) cm in height, and (20) cm in width as shown in Figure ٣. Figure ٤ shows standard specimens for erosion wear [9].

Erosion is a measure of the change in the angle (α) the liquid of the horizontal axis of the sample, at three levels (90^0,60^0,30^0). The streaming rate of fluid is (35 L/min). Sand water is the fluid used in the test erosion contains solid particles of abrasives with different sizes (425,600,800) µm. Erosion rate of the volume loss (ν) is defined by the following equation [10].

$$v = \frac{\varepsilon}{\rho} = \frac{WL}{WS(g)*\rho}$$
(6)

Where

ε: erosion rate of weight loss.

W_L: weight loss of the specimen.

Ws: total weight.

6. Results and Discussion

I. Mechanical tests

Hardness shore (D)

The results of Shore (D) hardness for the Epoxy resin (EP) reinforced with (G_1, G_2, and G_3) groups are illustrated in Table 4 and Figures ٥. It shows that the hybrid composites for G_2 and G_3 have the higher hardness and it increases with increasing the (fiber + particles) volume fraction. Adding the reinforcements (fiber + particles) can raise the material hardness even more may be the increase in material resistance against the plastic deformation [11]. Results has revealed also that the hardness of pure Epoxy alone is (76) compared to the maximum value of (82) for G_3 group (Epoxy +8%GF+8%SiC) as shown in Figure. The reason for the increased values of hardness is due to the increased cross-linking and stacking, which reduces the movement of polymer molecules and making it to become more resistant to the penetration of indenter [12].

Figure 3: Erosion wear device

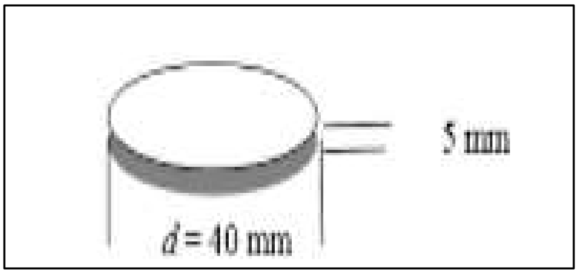

Figure 4: Erosion Wear standard specimens [10]

Table 4: Hardness shore (D) for (ER) reinforced with groups [G1, G2, and G3]

Type of composite	Hardness Shore (D)
Pure Epoxy	76
G_1	
Epoxy +4%GF+4%Sic	79
G2	
Epoxy +8%GF+4%Sic	80
G3	
Epoxy +8%GF+8%Sic	82

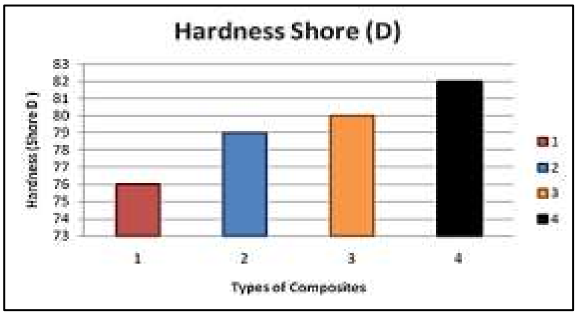

Figure 5: Hardness shore (D)
1- Pure Epoxy
2- Epoxy +4%GF+4%SiC
3- Epoxy +8%GF+4%SiC
4- Epoxy +8%GF+8%SiC

II. Physical tests

True Density

Table 5 and Figure ٦ shows the values of true density for the prepared hybrid composites. it can be seen that the true density of (Epoxy +8%GF+4%SiC) is higher than that of (Pure Epoxy), which is true since the glass fibers have higher density than epoxy and increasing its content can increase the density. The overall density will depend on the good distribution and bonding of all constituents [13].

Table 5: True density for (EP) reinforced with groups [G1 and G2]

Type of composite	True Density (gm/cm^3)
Pure Epoxy	1.06
G_1	
Epoxy +4%GF+4%Sic	1.16
G2	
Epoxy +8%GF+4%Sic	1.661

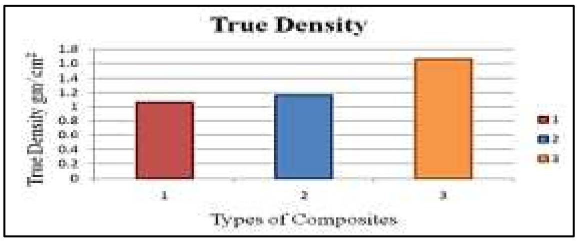

Figure 6: True density
1. Pure Epoxy
2. Epoxy +4%GF+4%SiC
3. Epoxy +8%GF+4%SiC

III. Erosion wear

The results of erosion wear for the Epoxy resin (ER) reinforced with (G_1, G_2, and G_3) groups are illustrated in Figure ٧. An (L^9) orthogonal array was used; a total of nine experimental runs must be conducted, using the combination of levels for each control factor (A–D) as indicated in Table 6 [14]. Table 7 show (L^9) values of erosion factors and levels. The role of erodent particles during the erosion process is to impact with certain velocity at the material surface. This continuously impact creates a localized rise in temperature, which facilitate the surface deformation by softening the matrix. Erosion occurs when the particles kinetic energy transfers to the materials body (ER or composites) and then leads to crater formation and subsequent material loss. The results show that the hybrid composites of experiment (8) give the lower erosion wear and then experiment (7) when they are compared with the other experiment. The reason is due to the presence of reinforcement materials in the material matrix that helps the kinetic energy absorption and thus become a viable energy of deformation less [15]. From the tables, it can be seen that the (Epoxy+8%GF+4%SiC) gives lower erosion wear than pure epoxy and (Epoxy+4%GF+4%Sic). This is due to the higher used volume fraction of SiC, which gives the composite higher hardness. However, composites with silicon carbide show better erosion resistance at (30°) impingement angle, (800 μm) erodent size and (10 hours) time, which may be related to bonding and good distribution of the particles of silicon carbide and hardness and has high strength and stiffness. Patnaik et al. [16], Show that the thermoplastic matrix composites usually show ductile erosion while the thermosetting ones erode in a brittle manner. They state that Collision angle be more standards in the erosion process and for ductile materials, the peak erosion occurs at 15° to 20° angle while for brittle materials the erosion damage is maximum usually at normal impact i.e. 90°

Table 6: Standard L (9) orthogonal array [14]

Experiment	(A)	(B)	(C)	(D)
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

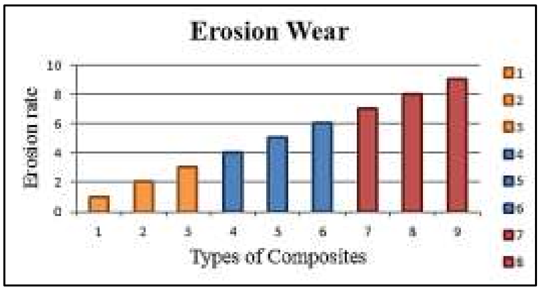

Figure 7: Erosion wear
(1- 3) pure epoxy
(4-6)Epoxy +4%GF+4%SiC
(7-9)Epoxy +8%GF+4%SiC

Table 7: L^9 values of erosion factors and levels

Experiment	Time (hr) (A)	Filler content (B)	Impingement Angle (°) (C)	Erodent size (µm) (E)	Total weight (Ws) (gm)	Weight loss (WL)	W_S-W_L (gm)	Erosion rate (ϵ) $W_L/W_S*\rho_t$
1	4	0%	30	425	6.2987	6.2051	0.0936	0.9293
2	4	0%	60	600	6.2987	6.0001	0.2986	0.8987
3	4	0%	90	800	6.2987	5.9911	0.3076	0.8973
4	8	Epoxy+4%GF+4%SiC	60	800	7.3119	7.2984	0.0135	0.8605
5	8	Epoxy+4%GF+4%SiC	90	425	7.3119	7.3004	0.0115	0.8607
6	8	Epoxy+4%GF+4%SiC	30	600	7.3119	7.3023	0.0096	0.8609
7	10	Epoxy+8%GF+4%SiC	90	600	8.9216	8.9203	0.0013	0.6019
8	10	Epoxy+8%GF+4%SiC	30	800	8.9216	8.9100	0.0116	0.6012
9	10	Epoxy+8%GF+4%SiC	60	425	8.9216	8.9210	0.0006	0.6020

7. Conclusions

The conclusions drawn from the present work are:

1. Epoxy resin (EP) has lower physical & mechanical properties than epoxy reinforced with hybrid reinforcement (GF+SiC).
2. The value of true density of the (Epoxy +8%GF+4%SiC) has the higher density of (1.661) (gm/cm^3) when compared with other composites.
3. Hybrid composites have higher hardness than pure epoxy, due to the combined effect of GF and particles. (Epoxy +8%GF+8%SiC) has the higher hardness of (82) shore D than with other hybrid composites.

(Epoxy+8%GF+4%Sic) give the lower erosion wear at (30°) impingement angle, (800 µm) erodent size and (10 hours) time than other used composites.

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