MECHANICAL PROPERTIES OF EPOXY BASED HYBRID COMPOSITES REINFORCED BY GLASS FIBERS AND SiC PARTICLES.

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ABSTRACT :

In the present study mechanical properties of pure epoxy and hybrid composites were studied. Pure epoxy and hybrid composites were prepared by Hand lay-up molding and investigated. The composites constituents were epoxy resin as the matrix, 4% and 8% volume fractions of glass fibers as reinforcement and 4% and 8% of silicon carbide as filler particles. The investigated mechanical properties were hardness, tensile properties (ultimate tensile strength (UTS), fracture strength), and impact properties (impact strength, fracture toughness). The experimental results showed that the mechanical properties, Hybrid composite with (Epoxy +8%GF+8% SiC) has the maximum hardness of (82) shore D, Hybrid composites with (Epoxy +8%GF+4% SiC) has the maximum (UTS), fracture strength, impact strength (G_c) & fracture toughness (K_c) of (107) MPa, (108) MPa, (9900) J/m^2, (27. 487) $MPa.m^{-1/2}$ respectively.

Keywords: Tensile, Hardness, Glass fibers, Hybrid composites.

الخواص الميكانيكية لمتراكبات هجينة اساس ايبوكسي مقواة بواسطةالياف الزجاج ودقائق السليكون كاربيد

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الخلاصة :

تم في هذا البحث دراسة الخواص الميكانيكية لمتراكبات هجينة ذات اساس من الايبوكسي. تم تحضير المتراكبات الهجينة وراتنج الايبوكسي بواسطة المقالبة اليدوية وتم فحصها. مكونات المواد المتراكبة كانت راتنج الايبوكسي كماده اساس و(4%، 8%) كسر حجمي من الياف الزجاج كمادة تقوية و (4%، 8%) من كاربيد السليكون كدقائق تقوية. الخواص الميكانيكيه التي تم فحصها كانت (الصلادة ، الشد (اقصى مقاومة شد ، مقاومة الكسر) والصدمة (مقاومة الصدمة ومتانة الكسر). أظهرت النتائج التجريبية بالنسبه للخواص الميكانيكية فأن المتراكبات الهجينة الحاوية على (ايبوكسي/8%الياف زجاج % 8%سليكون كاربيد) اعطت اعلى صلادة شور مقدارها (82) شور D ، والمتراكبات الهجينة مع (ايبوكسي / 8%الياف زجاج/ 4%سليكون كاربيد) كانت لها اعلى مقاومة شد ، مقاومة كسر، مقاومة الصدمة ، متانة كسر من (107 MPa) ، (108MP)و ($9900\ J/m^2$)، ($27.487\ MPa.\ m^{-0.5}$) على التوالي .

1. INTRODUCTION :-

Composites are a blend of two or more components, one of which is made up of stiff, long fibers or particulate material called a filler/reinforcement, and the other, a binder or 'matrix' or 'resin' which holds the filler in place. The matrix material can be polymeric (e.g. polyester resins, epoxies), metallic or ceramic. When the filler and the matrix are combined to form a composite, they retain their individual identities and structure influences the final composite properties Subita, B. et. al., [2013].

Initially conventional test methods originally developed for determining the mechanical properties of metals and other homogenous and isotropic construction materials were used Ranganatha, S. R. et.al., [2013].

Amiya Kumar et al., (2010) developed an epoxy based hybridized composite material comprising of glass fiber, jute fiber andred mud as filler material and evaluated its mechanical properties and observed that Flexural strength, tensile strength and density of the material increases with increase in number of layers of reinforcement Amiya Kumar Dash et.al., [2010].

Falak A. O. et. al. , (2010), studied the properties and behavior of particles on (glass, carbon, and Kevlar fiber) reinforced polyester composites. The effect of Al_2O_3 and SiC particles are investigated at different volume fraction (i.e. 0.2, 0.4, 0.6, 0.8, 1.0%). Comparative analysis showed that the impact resistance and hardness are increased with increasing the particles volume fraction especially (0.5%), and decreased for bending distortion especially in case of glass fiber/ polyester at (0.5%) volume fraction for both filler particles Abas F. O. et.al., [2010].

At the present, epoxy resins are widely used in various engineering applications, such as electrical industries, and commercial and military aircrafts industries. In order to improve their processing and product performances and to reduce cost, various fillers are introduced into the resins during processing Huang Z. M., [2000]. The aim of research: Prepare composites of Epoxy reinforced with glass fibers and silicon carbide (SiC) particles and Study of some mechanical properties (Tensile strength, Impact strength, Hardness (Shore D) tests of the prepared composites.

2. EXPERIMENTAL WORK :

2.1. Materials Used

The basic materials used to prepare the research samples consisting of Mat Glass fibers (GF) type (E-Glass) from the Tenax company_ England, Table 1 Shows typical Properties of Fibers Glass,and 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/cm3, Table (2) shows typical Properties of Epoxy resin Callister W. D. Jr, [2003]. It was used as the matrix.Silicon carbide (SiC) were used as reinforcing material. The type of the silicon carbide is F320. Density of silicon carbide is between 1.29-1.35 g/cm3 Surface chemical values are given in Table (3) Amir H.I., et.al. [2014].

2.2. Preparation of Composites

The hybrid composites samples were prepared fromEpoxy resin (matrix material) reinforced with Mat Glass fibers of (4% and 8%) volume fraction, and a particles of material Silicon carbide (Sic) of (4% and 8%) volume fraction. The method used in the preparation of the samples in this research is the (Hand lay-Up Molding) because it is simple to use and can make different shapes and sizes of composites. All the required moulds for preparing the specimens are made from glass with dimensions of (15×15×0.5) cm. The inner face of the mould has been covered with a layer of nylon (nylon thermal paper) made from poly vinyl alcohol material (PVA) instead of Vaseline so as to ensure no-adhesion of the resin with the mould. Figure (1) shows the shape of the prepared mould. The volume fraction of the

components is calculated based on the following relations Abdalla F. H., et.al. [2008]. Figure (2): Flow chart of the experimental work.

$$v_f = \frac{m_f}{\rho_f} \quad \text{.... (1)} \qquad V_f = \frac{v_f}{v_c} \quad \text{....} \quad \text{(2)}$$

$$v_m = \frac{m_m}{\rho_m} \quad \text{...} \quad \text{(3)} \qquad , \quad V_m = \frac{v_m}{v_c} \quad \text{.... (4)}$$

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.

Traditional and hybrid composites are prepared according to the following steps:

Preparation of Glass fibers woven of dimensions (15 * 15*0.5) cm according to the dimensions of the mould. The used volume fractions are (4% and 8%).

1- Weighting the reinforcing particles to specify a volume fraction of (4% and 8%).
2- Weighting the Epoxy resin depending on the volume fraction of reinforcement materials (fiber & particles), while taking into consideration the weight of hardener (3:1).
3- Mixing the Epoxy resin with the hardener continuously and slowly by using a glass rod so as to avoid bubbles. The mixing is carried out at room temperature.
4- Adding the particles intermittently into the mixture and stirring it for a period of (10-15) minutes to obtain Homogeneity. A rise in the temperature of the mixture will result as an indication to the beginning of the interaction process. It is very important that the mixture must have a good viscosity for the purpose of protecting the particles from precipitation which may result in the heterogeneity of the mixture that leads to the agglomeration after hardening.
5- Pouring the mixture into the mould, then putting the Glass fibers mat into the mould and continuing of mixture pouring until it covers all the mat.
6- For the purpose of completing the process of hardening, finally is leaving the sample in the mould for a period of (24) hour at room temperature.
7- Samples are then extracted from the mould and then heat treated in an oven at (60°C) for a period of (60) minutes Felix k., [2012]. This process is very important for the purpose of obtaining the best cross Linking between polymeric chains, and to remove the stresses generated from the preparation process and complete the full hardening of the samples.

3. MECHANICAL TEST :

3.1 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).

For each specimen five hardness measurements were taken and the average hardness is calculated.

3.2 Tensile Test

This test is performed according to (ASTM D638) at room temperature. Figure (3) shows standard specimens for tensile test Annual Book of ASTM Standard, [2000].

3.3 Impact Test

Impact resistance is calculated for samples from the following relationship Ipina J. E. P., et.al. [2000].

$$Gc = \frac{Uc}{A} \quad \text{..... (5)}$$

Where

G_c: impact strength of material (J/m^2).

Uc : impact energy (J).

A: cross- sectional area of specimen (m^2).

Fracture toughness can be expressed as Ipina J. E. P., et.al. [2000].

$$K_c = \sqrt{G_c E} \quad \text{..... (6)}$$

Where:

K_c: fracture toughness of material (MPa.m$^{1/2}$).

E: elastic modulus of material (MPa).

This test is performed according to (ISO- 179) at room temperature. Samples have been cut into the dimensions (80*10*5) mm. Figure (4) shows standard specimens for impact test ISO-179.asp.,[2006].

4. RESULTS AND DISCUSSION :

4.1 Hardness shore (D)

The results of Shore (D) hardness for the Epoxy resin (ER) reinforced with (G_1, G_2, and G_3) groups are illustrated in Table (4) and Figures (5). 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. 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 Ahmed J. K., et.al. [2011].

4.2 Tensile strength

Table (5) and Figures (6) and (7) shows the resulted values of ultimate tensile strength (UTS) and fracture strength for the Epoxy resin (ER) reinforced with (G_1, G_2, and G_3) groups. In general, it shows that the hybrid composites in G_2 group have given the higher values of UTS and fracture strength. Fibers are the main load carrying agents in composites and as the number of load carrying elements increases in a material, its strength increases, Also the tensile strength of the composites increases with increasing the fiber volume fraction Khanam P. N., [2010]. Weak cross-linking can cause a kind of friction between the reinforcements and base material, which leads to sliding between the particles Editer S. M. L., [1990]. This can be the reason for the lower UTS values in other hybrid composites. The decrease in strength with increasing the particles volume fraction may be due to non-wetting behavior of the filler particles with the matrix and may be due to the non-uniform distribution of the particles. The efficiency of load transfer between the matrix and reinforcements depends directly on the bonding which in turn depends on wetting of surfaces. The non-uniform distribution of particles may reduce wetting and bonding, and as a result of excessive particles that are not well dispersed in the polymer, stress concentrations and defects will be created in the matrix, and thus decreases the tensile strength Hanna W. A., et.al. [2011]. In general, the clustering or entanglement of particles and/or fibers in some areas and the irregularities may create resin poor areas and so weaken the forces of adhesion as well as creating many of defects within the composites and other defects formed within the fiber layer itself and that this will lead to the

generation of many areas to focus the stresses which accelerate the process of failure of the sample and making the material behave as a brittle MYERS D.S., [2006].

4.3 Impact energy

Table (6) shows the values of impact strength (G_c) & fracture toughness (K_c) for the Epoxy resin (ER) reinforced with (G_1, G_2, and G_3) groups. Figures (8) to (9) show the differences in results for each type of hybrid composites. The results of (G_c) & (K_c) for ER are lower than that of hybrid composites while maximum (G_c) & (K_c) for (Epoxy +8%GF+4%Sic) in **G_2** group. The reinforcements affect positively in bearing impact load and increasing the impact energy required to fracture the specimen.

The addition of particles during hybrid composite preparation can lead to form a high viscose mixture that may lead to decrease resin wettability which in turn weakening the linkage between matrix and reinforcement and that is an additional reason for the lower results of particle composites Saleh E. S., et.al. [2010]. Particle fillers (especially ceramics) may act as points for a localized stress concentration, from which the failure will begin, Also it may help in the reduction of elasticity of material and reducing the deformability of matrix and in turn the ductility, so that the composite tends to form a weak structure also, the bad distribution of fillers reduces the ability of matrix to absorb energy and thereby reducing the toughness, so impact energy decreases SAM A. R. M., [2007].The increase in fracture toughness may be related to particulate fillers that may act as obstacles that will retard the crack growth in the prepared composite system and this will cause the crack deflection in shape and direction i.e. blunting of crack tip will be expected, then toughness be increased, While decrease in the fracture toughness may be related to the bond weakness between the matrix and the particulate filler Hayder A. S., [2010].

5- CONCLUSIONS :

The addition of fillers (glass fibers and silicon carbide) to epoxy resin leads to an improvement of the hardness and mechanical properties. Following are the conclusions reached :

1- Increase in hardness of the prepared composite material with increase in the volume fraction of the glass fibers and silicon carbide. Hybrid composite with (Epoxy +8%GF+8%Sic) has the maximum hardness of (82) shore D than with other composites.

2- increase in (UTS), fracture strength of the prepared composite material with increase in the volume fraction of the glass fibers and silicon carbide. (Epoxy +8%GF+4%Sic) has the maximum (UTS), fracture strength, impact strength (G_c) & fracture toughness (K_c) of (**107**) MPa, (108) MPa, (9900) J/m^2, (27. 487) MPa.$m^{-1/2}$ respectively than other composites.

Table (1): Typical Properties of Fibers Glass type used in the search by the manufacturer specifications. (E-Glass)

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

Table (2): Typical Properties of Epoxy resin Callister W. D. Jr,[2003].

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

Table (3) Surface chemical values of F 320 silicon carbide Amir H.I.,et.al. ,[2003].

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

Table (4): Hardness shore (D) for (ER) reinforced with groups [G_1, G_2, and G3].

Type of composite	Hardness Shore (D)
Pure Epoxy	76
G_1	
Epoxy +4%GF+4%Sic	79
G_2	
Epoxy +8%GF+4%Sic	80
G_3	
Epoxy +8%GF+8%Sic	82

Table (5): Tensile strength for (ER) reinforced with groups [G_1, G_2, G_3].

Type of composite	σ UTS (MPa)	σ fracture (MPa)
Pure Epoxy	26.5	28
G_1		
Epoxy +4%GF+4%Sic	36	**51**
G_2		
Epoxy +8%GF+4%Sic	107	108
G_3		
Epoxy +8%GF+8%Sic	40.5	40.5

Table (6): Impact strength of material & fracture toughness for the (ER) reinforced with groups [G_1, G_2, and G_3].

Type of composite	impact strength of material (G_C) J/m^2	Fracture Toughness (K_C) $MPa.m^{-1/2}$

Pure Epoxy	578.51	7.867
	G_1	
Epoxy +4%GF+4%Sic	2525	14.864
	G_2	
Epoxy +8%GF+4%Sic	9900	27. 487
	G_3	
Epoxy +8%GF+8%Sic	3285	27. 248

Figure 1: Prepared mould

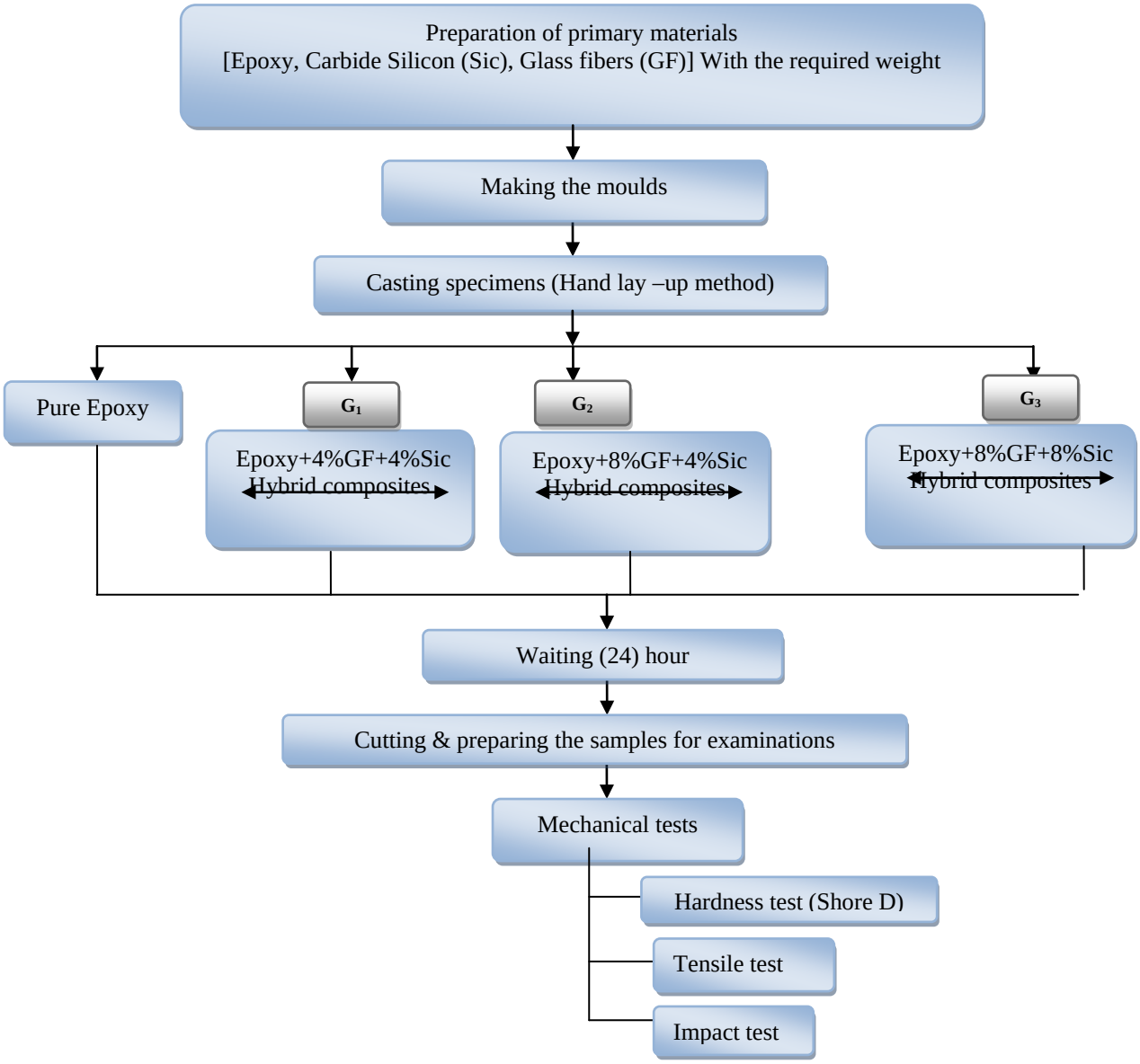
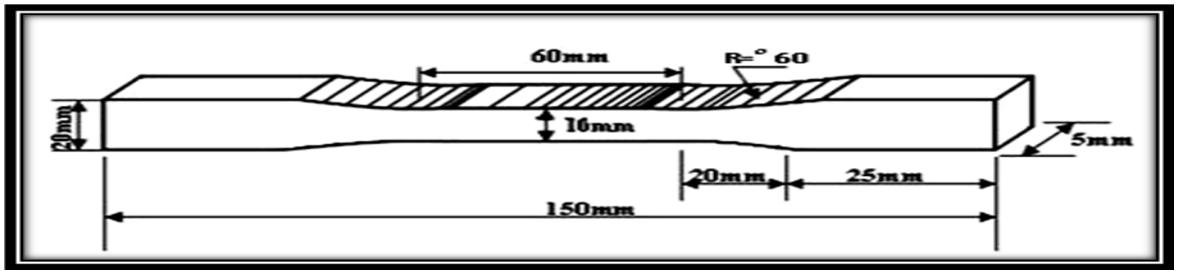
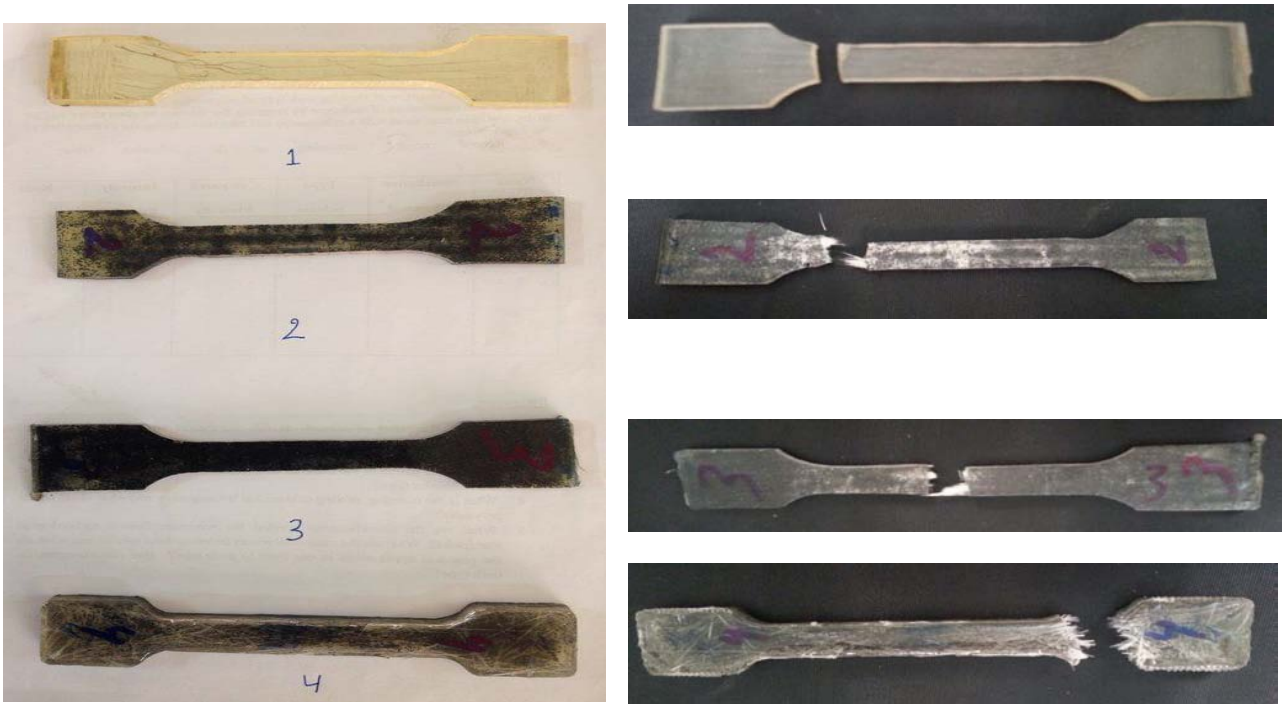


Figure (2): Flow chart of the experimental work



(a)

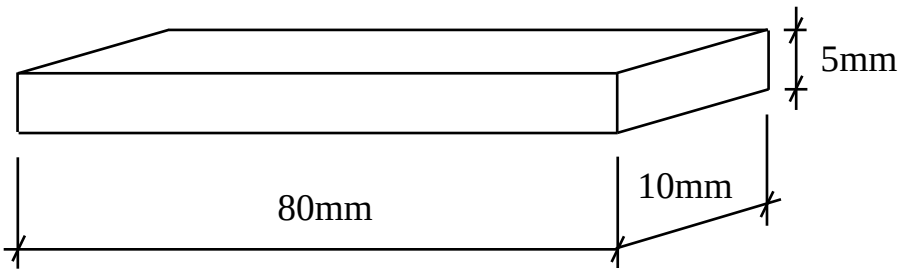


Before **(b)** **After**

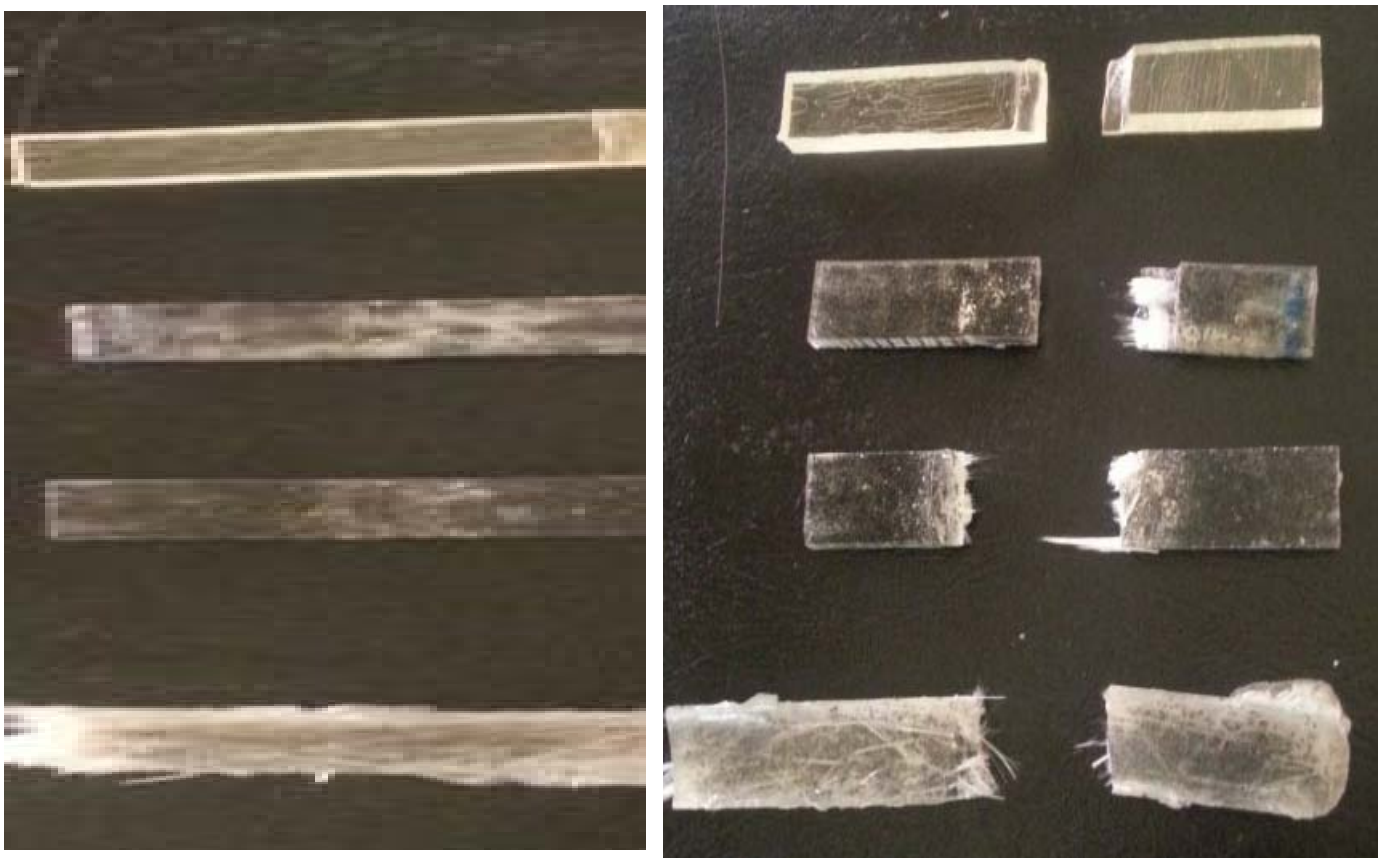
Figure (3) : (a) tensile test standard specimen Annual Book of ASTM Standard, [2000].

(b) Experimental specimens.

1-pure epoxy
2-Epoxy +4%GF+4%Sic
3- Epoxy +8%GF+4%Sic
4- Epoxy +8%GF+8%Sic



(a)

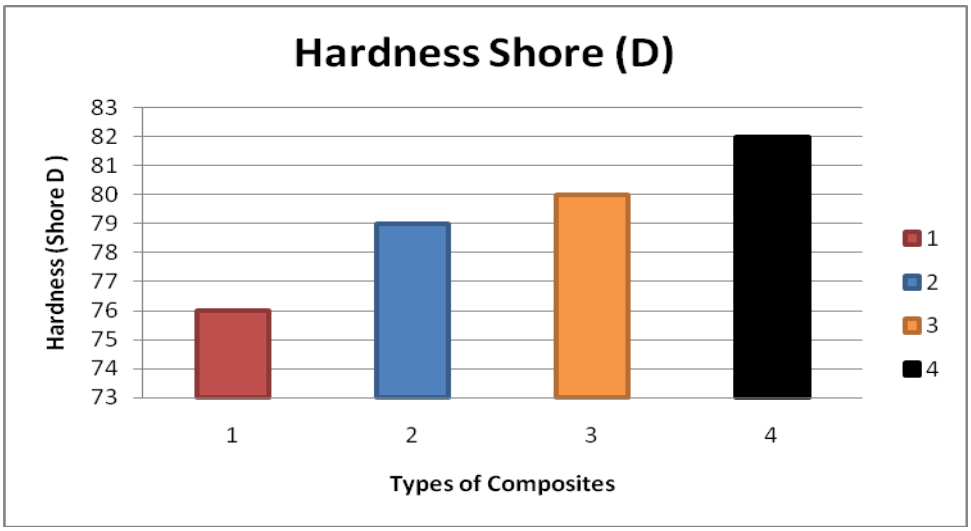


(b)

Figure (4) : (a) impact test standard specimen Ipina J. E. P.,et.al [2000].

(b) Experimental specimens.

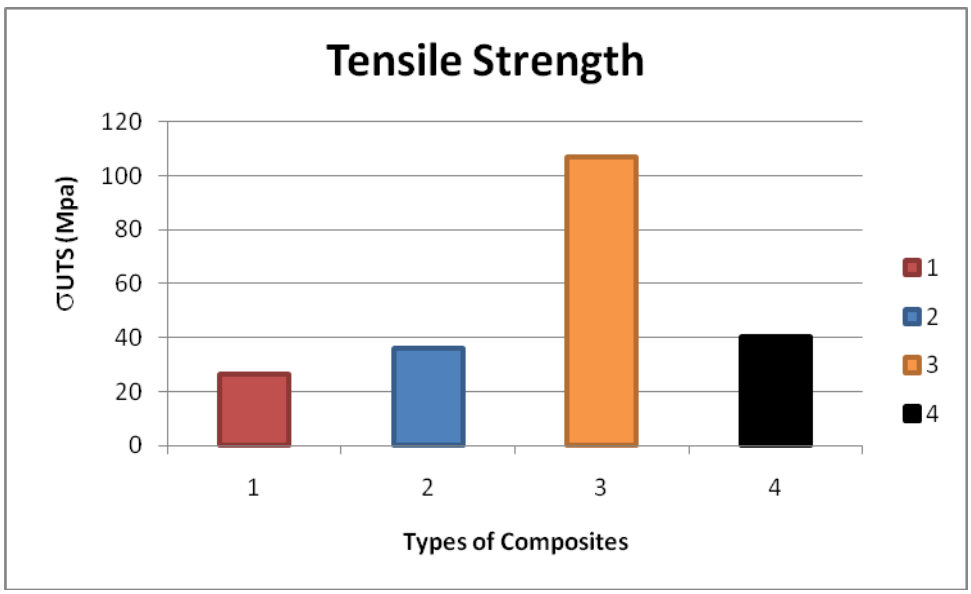
1-pure epoxy
2-Epoxy +4%GF+4%Sic
3- Epoxy +8%GF+4%Sic
4- Epoxy +8%GF+8%Sic



Figure(5) Hardness Shore (D):

1- Pure Epoxy **2- Epoxy +4%GF+4%Sic**

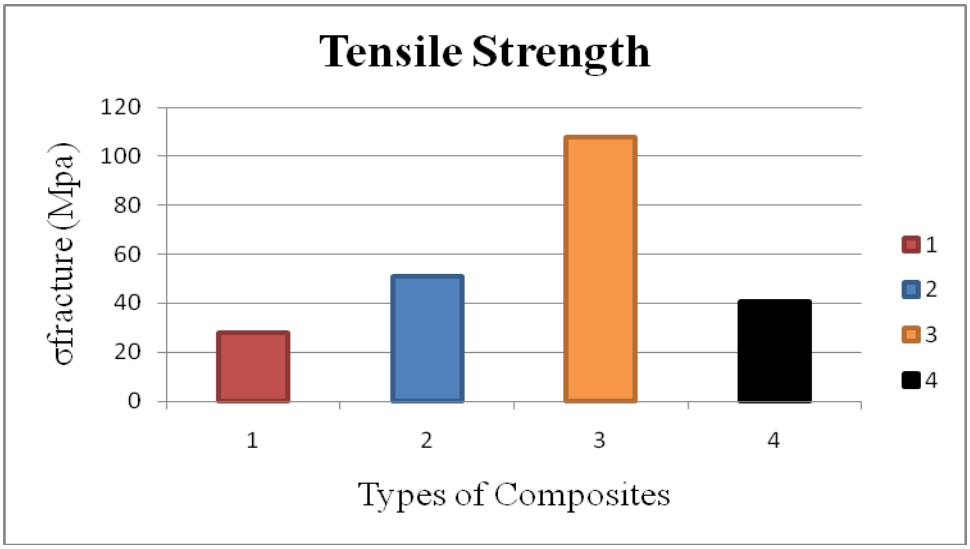
3- Epoxy +8%GF+4%Sic **4- Epoxy +8%GF+8%Sic**



Figure(6): UTS for :

1- Pure Epoxy **2- Epoxy +4%GF+4%Sic**

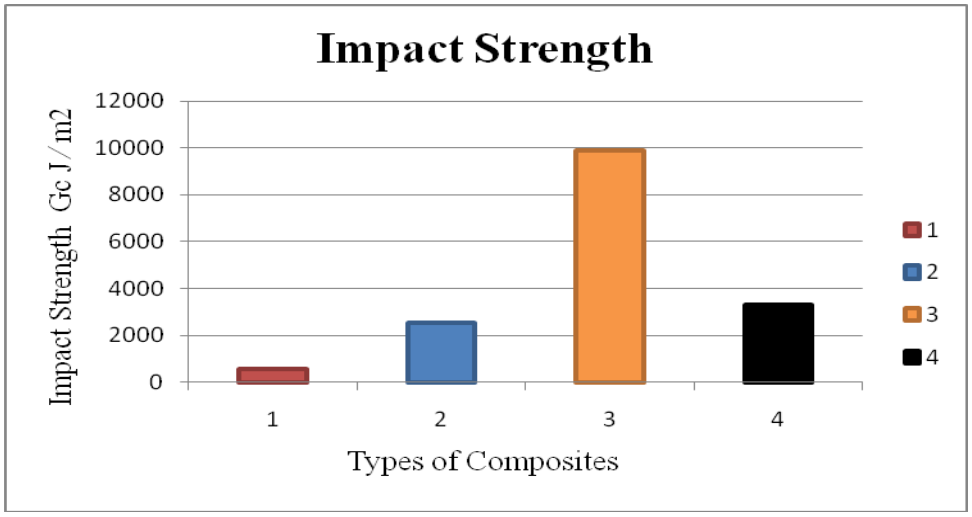
3- Epoxy +8%GF+4%Sic **4- Epoxy +8%GF+8%Sic**



Figure(7): $\sigma_{fracture}$ for :

1- Pure Epoxy **2- Epoxy +4%GF+4%Sic**

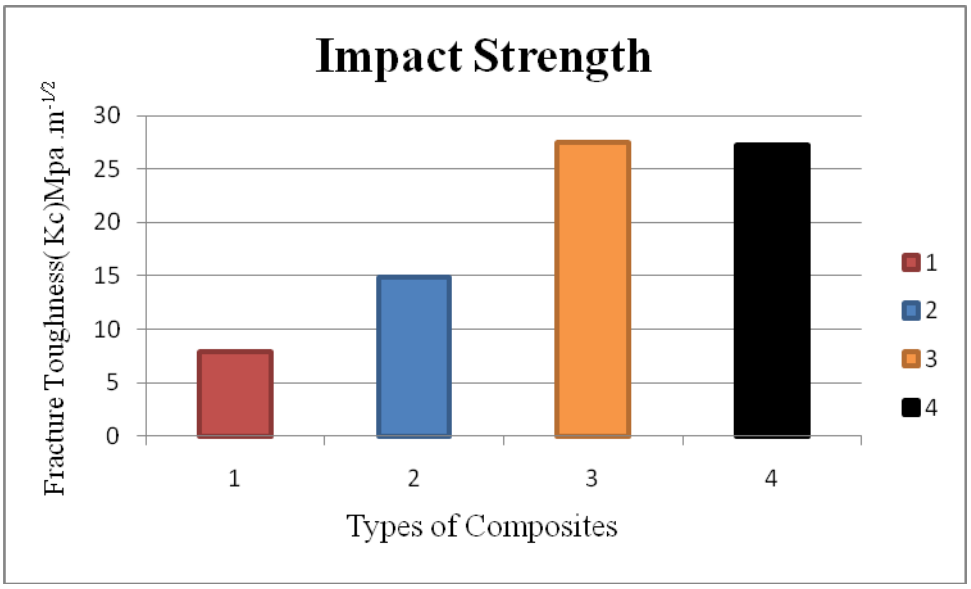
3- Epoxy +8%GF+4%Sic **4- Epoxy +8%GF+8%Sic**



Figure(8): Impact strength (G_c) for :

1- Pure Epoxy **2- Epoxy +4%GF+4%Sic**

3- Epoxy +8%GF+4%Sic **4- Epoxy +8%GF+8%Sic**



Figure(9): Fracture toughness (K_c) for:

1- Pure Epoxy **2- Epoxy +4%GF+4%Sic**

3- Epoxy +8%GF+4%Sic **4- Epoxy +8%GF+8%Sic**

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