The Effect of Utilization Aluminum Powder at the Mechanical Properties for Epoxy Resin

Harith I. Jaafar[1], Rihab Nassr Fadhil[2]

[1]Baghdad University/ College of Science/ Physics Dept. Iraq

[2]University of Baghdad, College of Education for pure Sciences/ Ibn Al Haitham, Physics Dept. Iraq

Abstract: *In this study, polymeric composite material were prepared a by hand- layup technique from epoxy resin as a matrix and Aluminum powder with particle size 7.1228μm as fillers with different weight percentage (0, 0.15, 0.25, 0.35, and 0.45) to resin. Mechanical properties such as three point bending and Hardness testing were investigated. The results show the flexural modulus (E) increase with increasing Aluminum percentage and it have maximum values of (8.1638MPa) for 45% Aluminum. Flexural strength, Fracture stress and Deflection decreases with increasing of the Aluminum percentages compared with pure Epoxy, except the ratio 15%, the Yield Points for all Aluminum percentage increasing with increasing ratio fillers. The results of hardness test show increase hardness with Aluminum concentration increase.*

Keywords: Aluminum, Epoxy, flexural modulus, hardness, three point bending

1. Introduction

A composite material is defined as: *"A substance consisting of two or more materials, insoluble in one another, which are combined to form a useful engineering material possessing certain properties not possessed by the constituents"* [1].

Polymer composite materials, based on a polymer matrix and inorganic micro particle fillers, have taken great attention among researchers, due to improvements in different properties including thermal, electrical, optical and mechanical properties [2].

We can change and control these properties for polymers by adding some filler, the types and the shapes of fillers will play important parameters to give the specific properties.

The purpose of the composite material is to get the materials characterized by a low density, good toughness, high tensile strength and stiffness, high performance at high temperature and high wear resistance and thermal conductivity, good hardness and resistance to fatigue and corrosion, hence the properties of composite materials depends mainly on the characteristics of each matrix and reinforcing materials as well as the nature of the interface between them so they are used as heat sinks in electronic packaging applications [3]-[5]. The characteristics of resin matrix are affected via the interfacial adhesion and particles size.

Epoxy resins are one of the most important class of thermosetting polymers, widely applied as surface coatings, structural adhesives and matrices for fiber- based composites [6], [7]. It has properties high mechanical strength, and chemical resistance. It is also well known that epoxy resins are rigid and brittle in nature, and have poor crack resistance in a real application [8], [9]. The aim of this work is to investigation effect of metal powder on the mechanical properties for composite.

2. Experimental work

2.1 Matrix Material

The matrix material that was utilized is epoxy resin (EP Euxit 50). it has a trademark (EP Euxit 50) production of SwissChem is a liquid of low viscosity resin, and it is converted to solid state by adding hardener (Euxit 50 KII) at ratio of (5:2), which were supplied by Egyptian Swiss chemical industries company .The properties of epoxy resin used in this work show in Table 1 according to the properties of Product Company ASTM D-543 and ASTM C-881-87.

Table 1: Show the properties of epoxy material.

Density at 20o C (gm/cm3)	1.05
Viscosity at 20o C	300
Flexural strength (MPa)	63
Modulus of elasticity(MPa)	2800
Fracture Toughness (MPa)	0.6
Colour	Colorless
Glass temperature o C	57
Bending property (N/mm2)	45

2.2 Aluminum powder

In this research, Aluminum powder (Density 2.7 g/cm^3 [10] and purity 99.0), was produced by the Company Central Drug House (P) Ltd, Vardaan House, New Delhi-10002, INDIA. The powder was adding to epoxy with weight percentage (0, 0.15, 0.25, 0.35, and 0.45). Scanning Electron Microscope (SEM) was use to determine the average diameter of particals which was (7.1228μm) as shown in figure 1
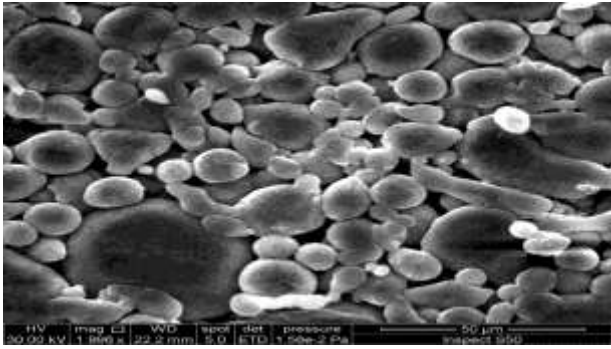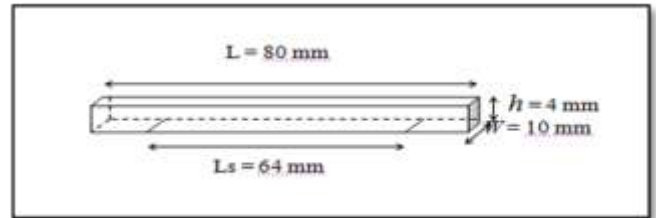
Figure 1: SEM image for Aluminum

2.3 Composite Fabrication

A hand lay-up method was used to prepare all the specimens in this work .Samples composed of epoxy resin with Aluminum powder at different weight percentage (0, 0.15, 0.25, 0.35, and 0.45), and the ratio of Epoxy to hardener is (5:2).To get good homogeneity between epoxy resin and Aluminum powder, homogenizer device at 700 rpm with 10 minutes to have good distribution for particles in epoxy resin. Vacuum system was used to remove the bubble before cast the composites in earlier prepared mold, blend was then poured into the mould, allowed to cure for 24 hours at room temperature (26 ± 2) ^{o}C.

3. Mechanical properties

3.1 Hardness test

Shore D was utilized to calculating the hardness of the composites, the prepared sample has (4mm) thickness and (30mm) diameter according to ASTM standard D-2240 [11] as shown in Figure 2.The shore D device involve a needle that is positioned vertically to the specimen, to register an accurate reading, the average of three values measured from various sites of each specimen is estimated.

Figure 2: Photograph of Shore D Hardness Test Specimens for pure Epoxy and Epoxy/ Aluminum composites

3.2 Three Point Bending

Three point bending test was carried out to test the specimens by using Instron 1122, with 5kN full scale load capacity. The force (load) was applied on the middle of specimen supported by two spans. The test was with descent speed load (1mm/min) and speed sheet drawing (10mm/min).

The samples shapes for three point bending test are identical to the specification of ASTM standard D-790 [12], as in figures 3, 4 and 5.

Figure 3: ASTM (D790).

The following equations can be used to calculate the flexural strength (σ f) and the flexural modulus (E):

$$\sigma_f = \frac{3FI}{2wh^2} \qquad (1)$$

$$E = \frac{I^3 S}{4wh^3} \qquad (2)$$

Where **I** Is the span of specimen, **w** is the width of the specimen, **h** is the thickness of specimen, **S** is the slope of the straight-line portion of force-deflection curve. Stress and strain are proportional to each other through the relationship. **F** Is the force applied at the mid span of specimen [13].

Figure 4: Photograph of Flexure Test Specimen for pure epoxy.

Figure (5): Photograph of Flexure Test Specimens for Epoxy/ Aluminum composites before testing

4. Result and Discussion

4.1 Hardness test

Figure 6 shows the variation values for Shore D Hardness of Epoxy resin and its composites. It has been found that the hardness values increase with the increasing of Aluminum powder ratio in the Epoxy composites, it was observed that there was an increasing in hardness values as Aluminum particles increase in Epoxy matrix until reach to 15% Al and then become semi- stable as the Aluminum particles increase in the Epoxy composite, This behavior is agreement with

[14],to explain this behavior, at low ratio, the particles of Al will distribute between the chain for epoxy, so that the indenter of device will touch the surface of specimen which contain deferent and small sizes of particles beside of epoxy. the increase Al powder, the Al particles will lined and clustered in all the volume of specimen, so that the indenter of device will touch the surface of clustered Al at the surface and the values of hardness will increase.
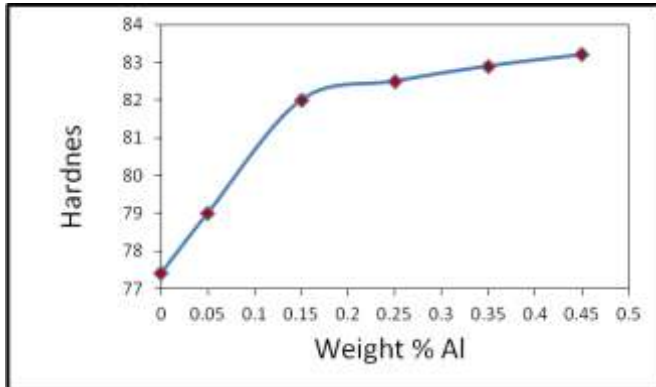

Figure 6: Shore D hardness of polymer composites as function of Aluminum powders.

4.2 Three Point Bending

Bending stresses are important in structure tests because of variety of loading situations in service. It determines the behavior and properties of the structure. Many parameters should be concerned test data. Polymeric composites are susceptible to mechanical damages when they are subjected to efforts of tension, flexural, compression which can lead to material failure [15].The mechanical properties of the materials are affected by many factors including: particles type, particle size, volume fraction, and specimen thickness [16].

Figure 7 shows that bending stress - strain curve for pure epoxy. The relationship between bending stress - strain is linear, this behavior is agreement with [17], to explain this behavior, epoxy is the thermoset polymer which has backbone chains, and because of the Epoxy has cross-linking between the backbone chains, the movement of these chains under force to bending the specimen. So that if the specimen is more bended the backbone chains will resist and the stresses will increase.
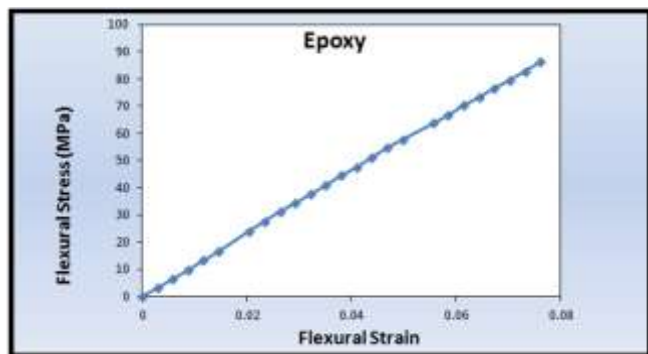

Figure 7: Flexural stress – Flexural strain curve for pure epoxy.

During the flexural test for composites, there are three factors dominate the resulting flexural strength of a specimen; the flexural strength of the matrix, the adhesion between fillers and matrix and the adhesion between the Particles and the characterization of filling materials. This means that, the last two factors are effect on the original strength of the matrix, and these two factors would lead to distribute the applied force on the cross-sectional area of the composite under test. Figure 8, observe the behavior Epoxy composites are different according to the weight percentage of filler, the curve include two regions, **linear** it's called elastic region and be under yield point, The linear region of the curve, shows that the applied stress on the specimen is distributed on the backbone of the polymer, because of the Epoxy has cross linking between the backbone chain restricts the movement of these chains under bending stresses [18]. **Non linear** it's called plastic region, the specimen is deformed, because of the concentration of the stresses at the lower region of the specimen (the convex side) where the specimen is extended, the stress will be constricted at the ends of crazes, which is grown to form the micro cracks, these micro cracks will be accumulated together to form the main crack, which pass through the specimen until the fracture occurs [19].

Table 2; show the flexural modulus (E) increase with increasing Aluminum percentage. Flexural strength, Fracture Force and Deflection decreases with increasing of the Aluminum percentages compared with pure Epoxy, except the ratio 15%, the Yield Points for all Aluminum percentage increasing with increasing ratio fillers. Figure 9 show Photograph of Flexure Test Specimens for Epoxy/ Aluminum composites after testing.
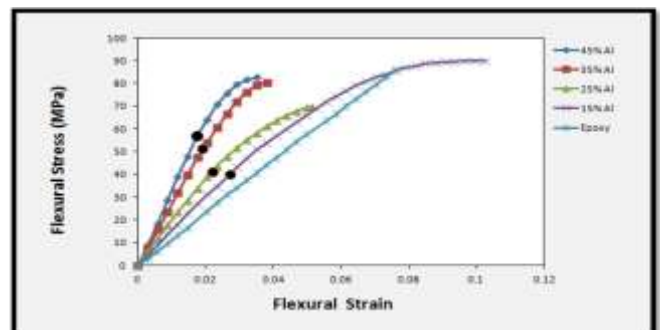

Figure 8: Flexural stress -deflection curve for Epoxy / Aluminum composite, ● refers to yield point.
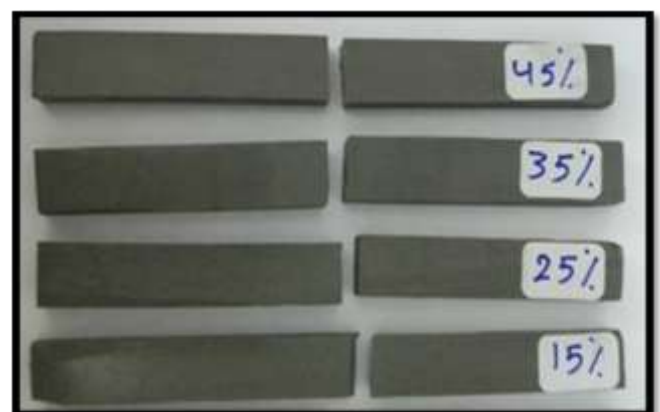

Figure 9: Photograph of Flexure Test Specimens for Epoxy/ Aluminum composites after testing.

Table 2: Values of Ultimate Maximum Flexural strength, Maximum Deflection, Maximum Fracture and Young Modulus for epoxy composites:

Materials	E (MPa)	Max. Fracture Force (N)	Max. Deflection (mm)	Max. σf (MPa)	Yield Point σy (MPa)
Epoxy	2.7880	143.5	5.2	86.1	------
15% Al	3.8596	150	7	90	39.95
25%Al	4.9005	116	3.5	69.6	41.11
35% Al	6.7376	134	2.6	80.4	51.5
45% Al	8.1638	138	2.4	82.8	57.0

5. Conclusions

The following Conclusions obtained from experimental work:
1) Flexural modulus (E) increase with increasing Aluminum percentage and it has maximum values of (8.1638MPa) for 45% Aluminum.
2) Flexural strength, Fracture Force and Deflection decreases with increasing of the Aluminum percentages compared with pure Epoxy, except the ratio 15%.
3) Yield Points for all Aluminum percentage increasing with increasing ratio fillers
4) Increase hardness with Aluminum concentration increase.

References

[1] William, D. Callister, Jr. "Materials Science and Engineering: An Introduction", 7th Edition. pp. 520-528, (2006)
[2] J. H. Koo, "Polymer Nano composite, Processing, Characterization and Application" Mc. GrawHill companies, USA (2006)
[3] Hakiki, Farizal et al., (2015). "Is Epoxy-Based Polymer Suitable for Water Shut-Off Application", Gas Conference and Exhibition and SPE/IATMI Asia Pacific Oil, SPE-176457-MS., (20).
[4] Xiaoliang Zeng et al., (2010) , "Preparation and characterization of epoxy/kaolinite nanocomposites", Jour. of Appl. Poly. Sci., 141: 461.
[5] Maciej Heneczkowski et al., (2014), " Epoxy Resin Composite Based on Functional Hybrid Fillers" www.mdpi.com/journal/materials, pp: 6064, ISSN (1996-1944).
[6] Bilyeu B., BrostowW., Menard K. P.: J. Mater. Educ. (1999), **21**, 281
[7] Bilyeu B., BrostowW., Menard K. P.: J. Mater. Educ. (2001), **23**, 189
[8] Varik, R.; Ille, A.; Vig, A.; Czajlik, I.; Rusznak, I. Radiat Phys Chem 1996, 47, 457.
[9] Ng, H.; Manas–Zloczower, I. Polym Eng Sci 1993, 33, 211.
[10] P.Keblinski and. S.R.Phillpot "J. Heat and Mass Transfer", vol. 45, no. 4, (2002), pp; 855-863.
[11] ASTM (D 2240). 2003
[12] ASTM (D790). 2003
[13] Norman Dowling "Mechanical behavior of materials: Engineering methods for deformation, fracture and fatigue", 2nd edition, (1999), Prentice Hall, ISBN-0-13-010989-4.
[14] S. I. Salih, S. Nayyef, A. H .Abd Alsalam, A. M. Hasan, "Evaluation Mechanical Properties of Polymer Composites Reinforced by different Metal Powders", Eng. &Tech.Journal, Vol.33, Part (B), No7, (2015)
[15] Segovia F., Salvador M.D., Amigo V. and Bloem C. "Shear strength characteristics in aged polyester-glass fiber composite", 12th International Conference on Composite Materials, Paris, July 5th - 9th, 1999.
[16] James F. Shackelford, "Introduction Material Science For Engineers" University of Califon by Peason Enduction, (2009).
[17] H. W. Abdullah, H. I. Jaffa, K. R. Al-Rawi, " Study of Bending Property for Epoxy / Kevlar - Glass Fibers and Hybrid Composite", Eng. &Tech. Journal, Vol.33, Part (B), No.9, (2015) .
[18] C.K.Riew & J.K.Gillham "Rubber – Modified Thermoset Resin", American Chemical Society, Washington, D.C, (1984).
[19] H.I.Jaffer "Ph. D Thesis "Physics Dep. College of Science, University of Baghdad, (2000).

Author Profile

Harith Ibrahim Jaafar, Born: 1962, Specialization: Physics Position: teaching, Scientific Degree: Professor. Work Address: Baghdad University/ College of Science/ Physics Dept.

Rihab Nassr Fadhil Al-Ameri, Born: 2/7/1984, Specialization: Physics, Position: Physicist, Scientific Degree: B.Sc. Work Address: College of Education for pure Sciences/ Ibn Al Haitham.