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Studying the Flexural Characteristics of the Epoxy Reinforced by Al and Cu Particles

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ABSTRACT:

In this research the flexural characteristics of the composite beam made from epoxy reinforced by (Al) and (Cu) particles with different volume fraction (3%, 6%, 9%, 12%, and 15%) where studied. The results show that the modulus of elasticity, the flexural strength and maximum shear stress increase with increasing the volume fraction of the reinforced particles of (Al) and (Cu), while the deflection decreases with the increasing the volume fraction. And the results show that the reinforcement with Cu particles give the best results than the reinforcement with Al particles. The maximum values of the modulus of elasticity, flexural strength and maximum shear stress for the epoxy reinforced by Cu particles was (4600 MPa.) ,(1535 MPa.) and (18.1 MPa.) respectively at the volume fraction (V_f =15 %).

دراسة خصائص الأنحناء للأيبوكسي المقوى بدقائق (Al) و(Cu)

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الخلاصة:

في هذا البحث تمت دراسة خصائص الانحناء لدعامة متراكبة مصنوعة من الايبوكسي المقوى بدقائق النحاس والالمنيوم عند كسور حجمية مختلفة (3%, 6%, 9%, 12%, 15%).

بينت النتائج بان كل من معامل المرونة وأجهاد الأنحناء وأقصى أجهاد قص يزداد مع زيادة الكسر الحجمي لمادة التقوية الدقائقية ، بينما التشوه يقل مع زيادة الكسرالحجمي لمادة التقوية. وكانت نتائج الأيبوكسي المقوى بدقائق النحاس أفضل من نتائج الأيبوكسي المقوى بدقائق الألمنيوم. وان اقصى قيمة لمعلمل المرونة وأجهاد الأنحناء وأقصى أجهاد قص للأيبوكسي المقوى بدقائق النحاس كانت على التوالي (4600 MPa.) و(1535 MPa.) و (18.1 MPa.) عند كسر حجمي (15%).

Most of the work concentrated on determining the deflection, Young's modulus and flexural strength of the composite beam against the applied load with different boundary conditions. The subject was taken experimentally.

G. Tolf and P. Clarin used the three-point bending test for composite materials to study the deflection and computing the Young's modulus(Goran Tolf and Per Clarin1984).

H. Soma et.al studied the flexural properties of metal-resin composite using Ag-Cu as a reinforcement particles and found that the flexural strength ranged from (49.6 MPa.) to (77.8 MPa.) and the flexural modulus of elasticity, ranging from (6.7 GPa.) To (11.9 GPa.)(H. Soma, Y. Miyagawa, and H. Ogura2003).

M.S. Sohn et.al studied the various reinforcing particles and different volume fraction on the dynamic mechanical property of particle-reinforced ethylene-propylene-diene monomer (EPDM) matrix composite, and shown that the dynamic elastic modulus values increase with increasing the volume fraction and shows that the composites with (20 Vol.% Cu) particles have the higher dynamic elastic modulus(M.S. Sohn, K.S. Kim, S.H. Hong, and J.K. Kim2003).

F.J. Lino et.al studied the flexural strength and the elastic modulus of the epoxy resin, aluminum filled epoxy and hybrid composite (aluminum particles and glass milled fiber) and found that the flexural strength and elastic modulus for hybrids composite give higher results than the aluminum filled epoxy (F.J. Lino, P.V. Vasconcelos, R.Paiva, and R.J.Neto 2004).

Ch. H. Lerchenthal and M. Brenman studied the flexural strength of thermosetting resins reinforced with cements and inorganic particles with volume fraction (20-85) % and found that the flexural strength of the specimens of with polyster resin give best results than the specimens of with epoxy resin(. H. Lerchenthal & M. Brenman, Ports1977) .

Young and Beaumont studied the some mechanical properties for the epoxy resin reinforced with silica particles with different volume fraction (0-52) % and found that the Young's modulus due to bending test increasing with increase the volume fraction of silica particles(R.J. Young & P.W.R. Beaumont1978) .

Narottam P. Bansal measured room temperature mechanical properties in three-point flexure and studied the influence of fiber volume fraction on mechanical behavior of CVD SiC fiber / $SrAl_2S_iO_8$ Glass-Ceramic matrix(Narrottam P.Bansal1996) .

B.P. Hughes and N.I. Fattuhi determined the various efficiency factors for steel and polypropylene fibers in cement-based composites with particular reference to flexural specimens (B.P. Hughes and N.I.Fattuhi 1977).

K. Kabo Yashi and R. Cho obtained fiber – reinforced concrete of superior toughness by dispersing short, discontinuous steel and polyethylene fibers, in randomly oriented states, in the concrete and found the maximum hybrid effect was obtained by (1 %) volume of steel fibers and (3 %) volume of polyethylene fibers (K. Koba Yashi and R. Cho 1982).

The purpose of this work is to study the effect of (Al) and (Cu) particles on the flexural analysis of the composite material for different particles volume fractions and make comparison between the two reinforcement.

In this research the specimens was made from five different volume fractions of (Al) particles and (Cu) particles which are (3 %, 6 %, 9%, 12% and 15 %), which represent the main factor that have an effect on the flexural characteristics of the composite beam.

Theoretical Analysis:

The flexural analysis of the composite beam made from polymer matrix composite reinforced with (Al) and (Cu) particles have been interested here because it has a wide range of application in the structure of the components.

Flexural analysis is used to determine the deflection, bending modulus and flexural rigidity of the beam which depends on their constituents (matrix and particles) and geometry.

Flexural analyses of the composite material behave in a different manner from that of one – element material, this difference may be viewed by deflection value and it may be higher or lower than that of the one element material according to the rule of mixtures.

From theory, the flexural strength (F.S.) can be estimated from the following formula(G.C. Ives, G.A. Mead & M.M. Riley1971, B.R. Sanders and T.L. Weintraub1985) .

$$F.S. = \frac{3 \cdot P \cdot L}{2 \cdot b \cdot d^2}$$

P - Maximum applied force of failure point (N)
L - Length of the specimen (m)
d - Width of the specimen (m)
b - Thickness of the specimen (m)
And the Young's modulus due to bending (E_{bend}) can be determined by the following formula (William D. Callister J 2003,Hearn, E.T.1987).

$$E_{bend} = \frac{F \cdot L^3}{48 \cdot I \cdot \delta}$$

Where
F - Applied force (N)
I - Moment of Inertia (m^4)
δ - Deflection of the specimen (m)

Also the maximum shear stress can be determined from the following formula:

$$\tau_{max.} = \frac{3 \cdot p}{4 \cdot b \cdot d}$$

The elastic constants of a particulate composite must be determined in terms of the properties of the particles and the matrix and in terms of the relative volumes of them(R.M.,Jones 1975) [14]. Thus

Upper bound on the apparent Young's modulus (E_u *)*

$$E_u = E_p \cdot V_p + E_m \cdot V_m$$

And the lower bound on the apparent young's modulus (E_L *)*

$$E_L = \frac{E_m \cdot E_p}{E_p \cdot V_m + E_m \cdot V_p}$$

Where:
E_p, E_m – Young's modulus of the particles and the matrix respectively.
V_p, V_m – Volume fraction of the particles and the matrix respectively.

Experimental Work:

The experimental work was carried out in the polymer labrotary to determine experimentally the deflection, young's modulus, flexural strength and maximum shear stress.

The particulate composite test specimen is composed of epoxy type (Quickmast 105) from DCP company (Don Construction Product Ltd.) as a matrix and (Al) and (Cu) particles with grain size (30 µm) from (RIEDEL-DE HAEN AG) Germany company as a reinforcement with the following volume fractions (3%, 6%, 9%, 12% and 15%) and table (1) represent the some properties of the materials used in preparation the specimens. The hardener type was (Quickmast 105) from company DCP with ratio (3:1) i.e. (for each 3 gm from epoxy 1 gm hardener)(William D. Callister J 2003, N.G. Mccrum, C.P. Buckley & C.B. Bucknall1997) .

Figure (1) represents the three–point device with tested specimen which is fixed horizontally by simple supported at both ends. And make experimental work by acting a rate of weight at the middle of the specimen in order to obtain the deflection and the load from both dial gauge and applied load.

The test specimen of the composite beam has a length of (191 mm) and width of (13 mm) and a thickness of (4.8 mm) according to (ASTM D-790).

Results and Discussion:

The results obtained from experimental work for the flexural of the composite beam specimens made from Epoxy matrix reinforced with different volume fraction of (Al) and (Cu) particles.

Figures (2 and 3) show the relationship between load and deflection of the composite beam reinforced by (Al) and (Cu) particles at different volume fraction (3%, 6%, 9%, 12% and 15%) respectively.

It is clear from these figures that the deflection increases in linear relationship with increasing the load at different rate that depend on the volume fraction of the reinforcement particles.

Also for the same value of volume fraction (15%) and for the same value of load (10 N), it can be seen that the deflection was (1.35 mm) for the specimen reinforced by (Cu) particles, while was (1.7 mm) for the specimen reinforced by (Al) particles.

Figure (4) shows the relationship between the central deflection of the composite beam reinforced by (Al) and (Cu) particles with the volume fraction of these particles.

It can be seen that the deflection decrease with the increasing the volume fraction of (Al) and (Cu) particles in nonlinear relationship.

Also it was found that the deflection of the composite specimen reinforced by (Cu) particles was less than the deflection of the composite specimen reinforced by (Al) by the value of (20.6%), because of the bonding force between (Cu) particles and epoxy was higher than the bonding force between (Al) particles and epoxy due to wetability of (Cu) particles was higher than the wetability of (Al) particles(William D. Callister J 2003).

Figure (5) represents the relationship between the modulus of elasticity and the volume fraction of the reinforcing material. It can be seen from this figure that the modulus of elasticity increase in nonlinear relationship with the increase the volume fraction of the metallic particles (Al) and (Cu). Also found that the modulus of elasticity of the epoxy was (1550 MPa.), while the modulus of elasticity of epoxy matrix reinforced by (Al) and (Cu) particles at (V_f =15 %) were (3600 MPa. and 4600 MPa.) respectively, because of that the (Cu) particles have higher bonding with epoxy than that the (Al) particles with epoxy.

Figure (6) shows the relationship between the flexural strength and volume fraction of the composite beam reinforced by (Al) and (Cu) particles. It is clear from this figure that the flexural strength of the epoxy matrix reinforced by (Cu) was higher than the flexural strength of the epoxy matrix reinforced by (Al) by the value (36.5%) at (V_f=15 %).

Figure (7) shows the relationship between the maximum shear stress and volume fraction of the composite beam reinforced by Al and Cu particles.

It can be seen from this figure that the maximum shear stress increase in nonlinear relationship with the increasing the volume fraction of Al and Cu particles.

Also it was found that the maximum shear stress of the composite beam reinforced by Al and Cu particles was (14.5 MPa.) and (18.1 MPa.) respectively while the max. shear stress for the unreinforced epoxy was (2.5 MPa.).

Conclusion:

The main conclusions of the present work are:

1-) The maximum percentage of deflection for the epoxy reinforced by (Al) particles was higher than that for epoxy reinforced by (Cu) particles by the value (20.6 %) at (V_f =15%).

2-) For the same value of (V_f =15 %), the modulus of elasticity of the epoxy reinforced by Al and Cu particles was (3600 Mpa.) and (4600 Mpa.) respectively while the modulus of elasticity of unreinforced epoxy was 1550 Mpa.

3-) flexural strength of the composite beam reinforced by Cu particles was higher than that reinforced by Al particles by the value (36.5%) at (V_f=15%).

4-) Maximum shear stress of the composite beam reinforced by Cu and Al particles was (14.5 MPa.) and (18.1 MPa.) respectively, while the maximum shear stress for unfeinforced epoxy was (2.5 MPa.).

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Table (1): Some Properties of the Constituents (K. Koba Yashi and R. Cho 1982 ,William D. Callister J 2003)

Materials	Density (kg/m^3)	Young's Modulus (GPa.)	Tensile Strength (MPa.)	Yield Strength (MPa.)
Epoxy	1.11-1.4	2.41	27.6-90	-
Al	2.7	71	110	34
Cu	8.9	130	220	69

Figure (1): Flexural Apparatus with Specimen Test.

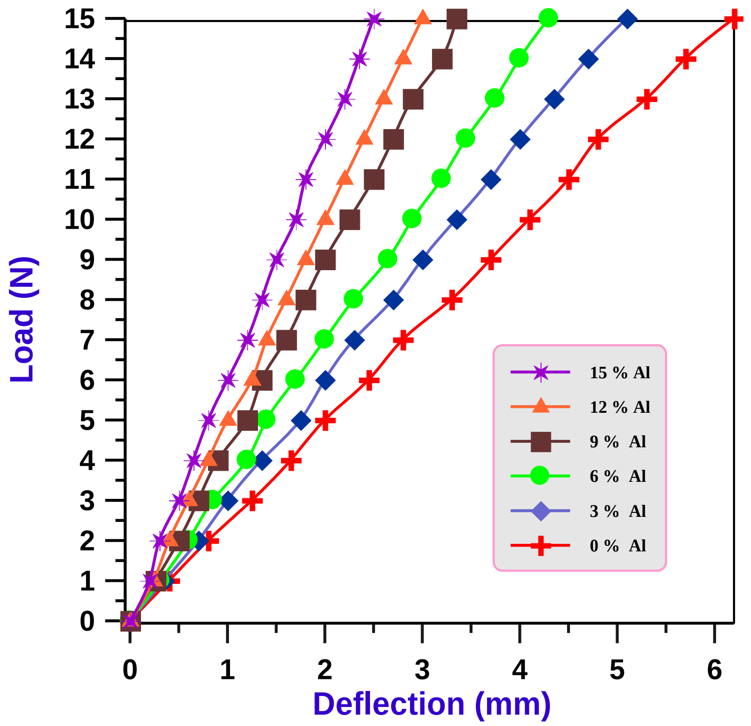

Figure (2): Relationship Between the Load and Deflection for the Epoxy Reinforced by (Al) Particles with Different Volume Fractions.

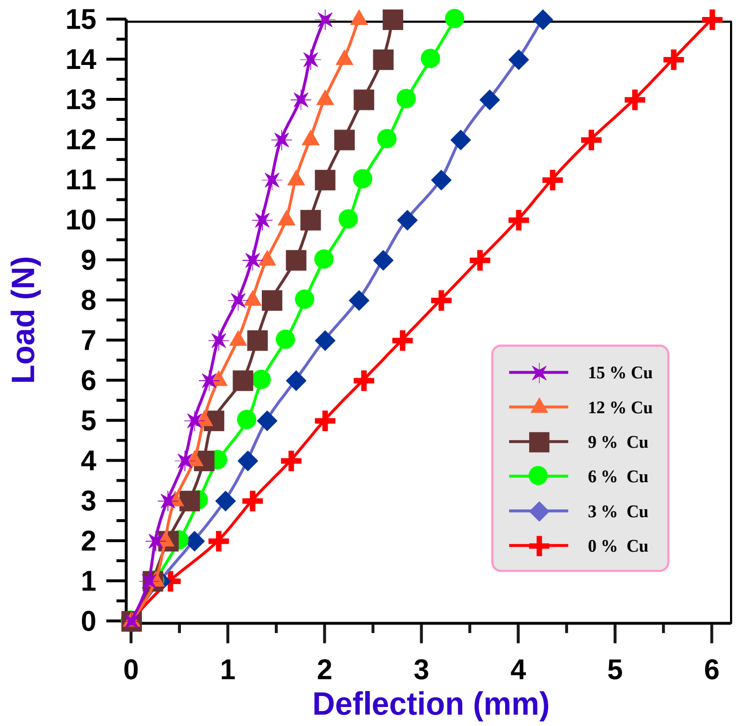

Figure (3): Relationship Between the Load and Deflection for the Epoxy Reinforced by (Cu) Particles with Different Volume Fractions.

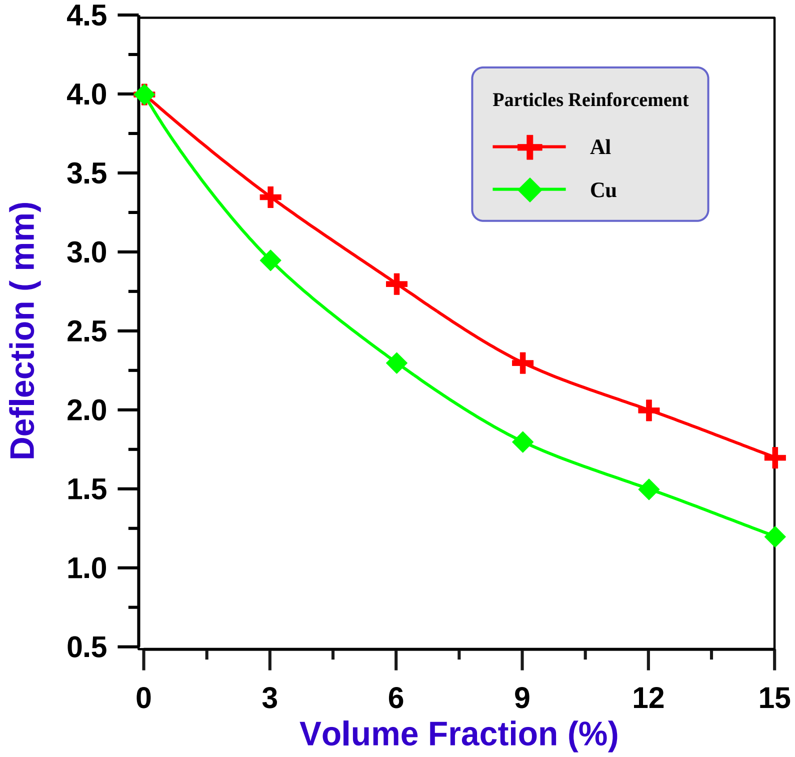

Figure (4): Relationship Between the Deflection and the Volume Fraction of the particles Reinforcement at the Load = 10 N.

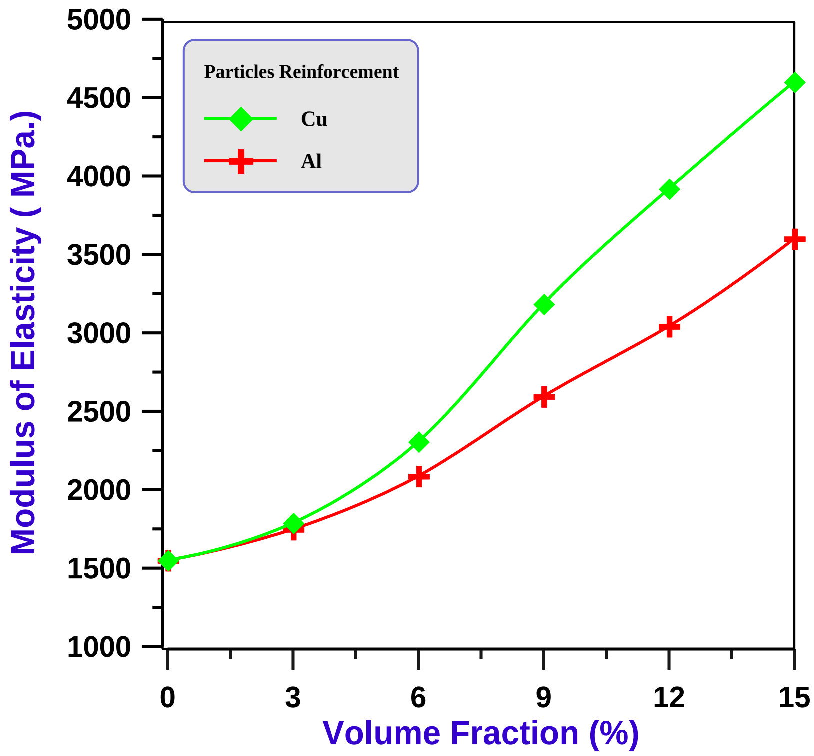

Figure (5): Relationship Between the Modulus of Elasticity and the Volume Fraction of the particles Reinforcement.

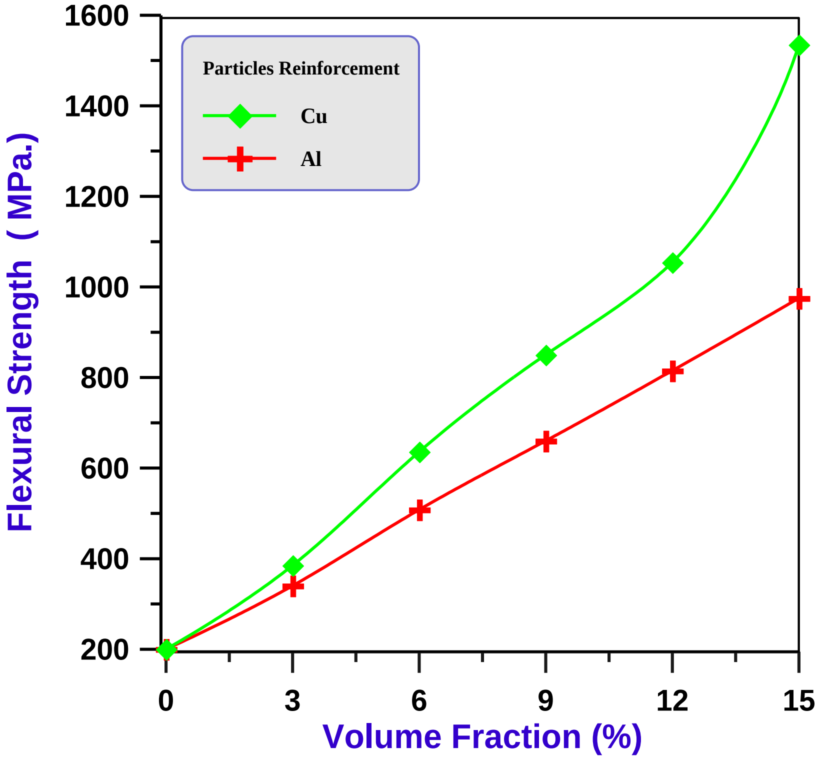

Figure (6): Relationship Between the Flexural Strength and the Volume Fraction of the particles Reinforcement.

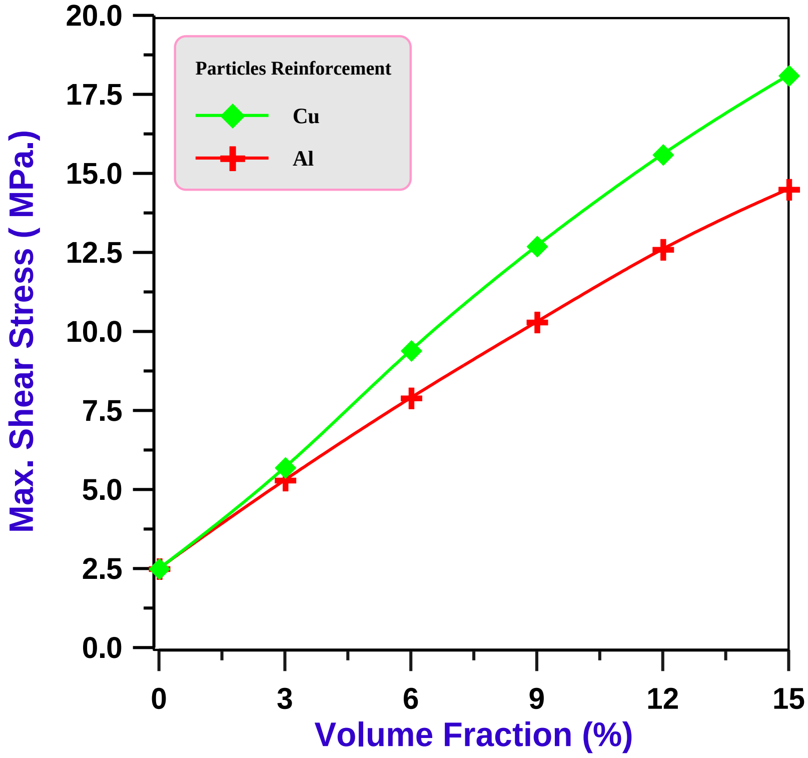

Figure (7): Relationship Between the Max. Shear Stress and the Volume Fraction of the particles Reinforcement.