Study of Bending Property for Epoxy / Kevlar - Glass Fibers and Hybrid Composite

The 5th International Scientific Conference for Nanotechnology and Advanced Materials and Their Applications ICNAMA 2015 (3-4) Nov.2015

Hind W. Abdullah
College of Science, University of Diyala/ Diyala.
Dr.Harath I.Jaffa
College of Science for woman, University of Baghdad/ Baghdad.
Dr. Khalid R. Al-Rawi
College of Science for woman, University of Baghdad/ Baghdad.
Email: alrawikad@yahoo.com

ABSTRACT

In this research a study of the effect of quality , sequential and directional layers for three types of fibers are : Kevlar fibers-49 woven perpendicular and E- glass fiber woven perpendicular and random on the bending using epoxy as matrix. Hand – lay up method was used to fabricate epoxy composite and three layers from Kevlar fiber as well as epoxy composites and three layers of glass fiber and then hybrid composite was fabricated in the shapes: (Kevlar - regular glass - Kevlar) layers, (Kevlar - random glass –Kevlar) layers , (regular glass-Kevlar- regular glass) layers. The results shown that for Bending test the sample which reinforced (Kevlar - regular glass-Kevlar) characterized the highest bending (8mm) and The less bending reinforced sample was (regular glass-Kevlar- regular glass) (4.5mm) even it less than the reinforced sample (Kevlar - regular glass – Kevlar).

دراسة خاصية الانحناء لمتراكبات الايبوكسي المدعمة بالياف الكيفلر و الزجاج و متراكبات هجينة

الخلاصة

تم في هذا البحث دراسة تأثير نوعية و اتجاه و تتابع الطبقات لثلاث انواع من الالياف و هي كيفلر 49 المنسوجة عموديا و الياف زجاجية E– منسوجة عمودي و عشوائي الانحناء باستخدام مصفوفة epoxy .استخدمت طريقة Hand –lay up لتشكيل مركب epoxy و ثلاث طبقات من الياف كيفلر بالاظافة الى مركبات الepoxy و ثلاث طبقات من الالياف الزجاجية و من ثم مركبات هجينة شكلت في اشكال من طبقات : (كيفلر – زجاج عادي – كيفلر) ، (كيفلر – زجاج عشوائي – كيفلر) و (زجاج عادي – كيفلر- زجاج عادي) .النتائج اظهرت ان اختبار الانحناء للعينة المعززة في (كيفلر – زجاج عادي – كيفلر) تتميز باعلى انحناء (8 mm) و العينة اقل انحناء كان (زجاج عادي –كيفلر- زجاج عادي) (4.5 mm) .

INTRODUCTION

Fiber reinforced plastics have been widely used for manufacturing aircraft and spacecraft structural parts because of their particular mechanical and physical properties such as high specific strength and high specific stiffness. Another relevant application for fiber reinforced polymeric composites (especially glass fiber

https://doi.org/10.30684/etj.2015.117371
2412-0758/University of Technology-Iraq, Baghdad, Iraq

reinforced plastics) is in the electronic industry, in which they are employed for producing printed wiring board. [1]

Composite materials are constituted of two phases: the matrix, which is continuous and surrounds the other phase, often called as reinforcing phase. Epoxy resins are widely used as matrix in many fiber reinforced composites; they are a class of thermoset materials of particular interest to structural engineers owing to the fact that they provide a unique balance of chemical and mechanical properties combined with wide processing versatility. [2]

Hybrid composites are being investigated throughout the globe because they have enhanced properties than their mother composites which are relatively cost effective. The mechanical properties like bending, fatigue, stiffness and strength of kevlar-glass/epoxy hybrid laminates were reported by the researchers[3]

Hybrid composite materials have successfully substituted the traditional materials in several lightweight and high strength applications.

The development of composite materials improves their performance based on the reinforcement of two or more fibers in a single polymeric matrix which leads to the advanced material system called hybrid composite with a great diversity of material properties. Thus, there is a need to investigate the mechanical properties like hardness, tensile strength, compression strength and flexural strength. The properties of a hybrid composite mainly depend upon the fiber content, length of individual fiber, orientation, extent of intermingling of fibers, fiber to matrix bonding and arrangement of both the fibers. The strength of the hybrid composite is also dependent on the failure strain of individual fibers. Maximum hybrid results were obtained when the fibers are highly strain compatible. [4,5]

Experimental work

Materials used:

Epoxy resin type (Quick mast 105) was provided by DCP Company / Jordan with specific gravity (1.04) is used with its hardener in ratio (1:3).The epoxy was mixed with a hardener in a container to form a mixture was used to prepare composites.

The volume fraction of matrix and reinforcement material is calculated from the following equations [9]. Volume fraction of matrix:

$$V_m = \frac{V_m}{V_c}\%$$

Reinforcing material :1-E- Glass fiber :Uniform(GW) and random(GR) E-glass fibers

2-Kevlar fiber In general there are three main types of this fiber that are produced by Du Pont Co. with different trade marks (29, 49 and 149). The one that was used in this work was type (49). It has woven roving shape as shown in Fig.(1). Table (1) shows some of the properties of the two above-mentioned types.

Table (1): Properties of E – glass and Kevlar (49) fibers[6]

Fiber	Density (g/cm3)	Diameter (μm)	Tensile Strength (GPa)	Young's Modulus (E,GPa)	Fracture Strength (σ,GPa)
E-glass	2.6	1.1	3.33	76	2
Kevlar49	1.45	12	3.62	130	3

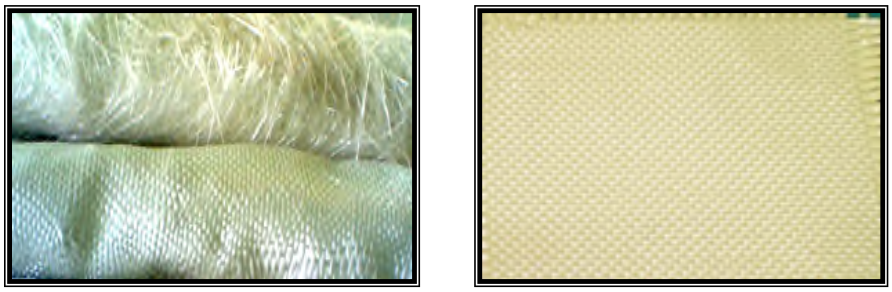

Figure (1): Photographic image of pieces of the fibers used (a) E-glass fibers, (b) Kevlar fibers

Sample Preparation

Hand – lay up method was used to fabricate epoxy composite and three layers from Kevlar fiber as well as epoxy composites and three layers of glass fiber and then hybrid composite was fabricated in the shape s: (Kevlar - regular glass - Kevlar) layers , (Kevlar - random glass –Kevlar) layers , (regular glass-Kevlar- regular glass) layers., The sheets were left to solidify at room temperature (26 ± 2) C^o. The glass mould of frame was (10 ×10× 4) cm used for casting the sheet of composite material. It Wax was fixed on the inner mould faces before casting to ensure the releasing of casting composites and having smooth faces.

Flexural Strength

Three-point Bending tests was used to study the flexural of the specimens and it was carried out by using Instron universal testing machine of 5 kN full scale load capacity according to ASTM standard (D-790). The five rectangular specimens have frame dimensions (15×15) cm. Flexural strength of the composites was calculated according to [5]

$$\sigma \max = 3FS / 2 bd2 \quad ...(1)$$

Where F: is the applied central load (N), L: support span, b and d: width and thickness of the specimen (mm). Elasticity modulus was calculated according to

$$E = L3m/4bd3 \quad \ldots(2)$$

where m is the slope of the tangent to the initial straight line portion of the force-deflection curve. The maximum tensile strain was calculated according to

$$\varepsilon = 6Dd/L2 \quad \ldots(3)$$

D is the deflection beam at a given point on the load –deflection data.

Results and Discussions

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[7]. The mechanical properties of the materials are affected by many factors including: fiber type, volume fraction, direction of the fiber, specimen thickness[8]. Fig(2)show that flexural stress - deflection curve for pure epoxy that the relationship is linear with the increase of

stress after yield point referred to in the figure, which is the boundary between the elastic deformation and the ductile deformation. Stress constantly from top to bottom expanding (craze) to lead to (crack) starting from the bottom surface of the sample and spread toward the upper surface of the sample, leading to the break. The reason is due to the fact that the polymeric chains consisting of the sample are intertwined, when you shed the stress on the sample will lead to the occurrence of landslides in the polymeric chains and move those chains in various directions until the occurrence of break-up[9] , while the composite samples show a different behavior according to the type of fiber although they where common to have a linear behavior initially and after noted displacement, where the curve began to fluctuate as shown in Fig.(3,4). table (2)

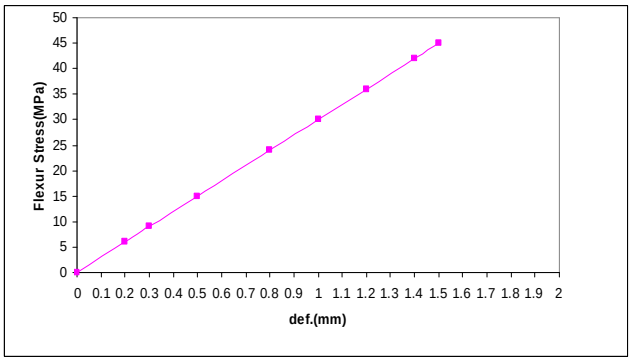

Figure (2) flexural stress -deflection curve for pure epoxy .

Table (2) Values of Ultimate Max. stresses, Yield Stresses and Young Modulus for epoxy composites

Specimen	E (GPa)	F.S (MPa)	Yield point (MPa)	Def. at Max. Stress (mm)
EP	3.2	45	30	1.5
3K/EP	5.15	111	88	7.5
3G/EP	7.5	193	144	7.3
3KGK/EP	7.13	171	132	8
3KGRK/EP	5.6	121	108.8	6.5
3GKG/EP	5.6	155	89	4.3

Fig.(3,4) show that the flexural stress-deflection curves for epoxy reinforcement by (3 layers glass fiber(3G/EP ,3layers Kevlar fiber3K/EP) composites. It is known, that the mechanical properties of polymers can be improved by reinforcing them with fibers. During the flexural test, there are three factors dominate the resulting flexural strength of a specimen; the flexural strength of the matrix, the adhesion between fibers and matrix and the adhesion between laminates. This means that, the last two

factors are added to the original strength of the matrix, and these two factors would lead to distribute the applied force on more cross-sectional area of the composite under test. Fig.(3,4) there are two noticeable regions: the elastic region, and plastic region, it shows that the molecules slip passes each other normally to a small extent. After that point the craze show up which the material begin to deform numerous micro voids, The crack is initiated in the outer layer of the samples. The mechanism of failure is occurring when the critical state of stress in samples is reaching that will cause the appearance of critical value of crack and its unstable growth. The position of critical crack is associated with the fiber matrix debonding after which the fibers cracked. When the first break in the outer layer appeared it follows by more broken fibers (which was debonded and pulled out from the matrix). The crack propagates from the outer to the inner surface sample in transversal direction. The crack and delaminating appears in the samples as a result of shear stresses in the layers which is characteristic of bending test [10]. [11].

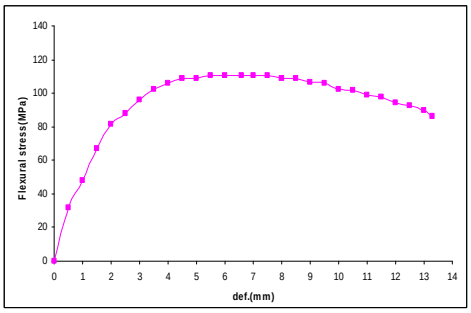

Figure (3) flexural stress -deflection curve for 3k/EP

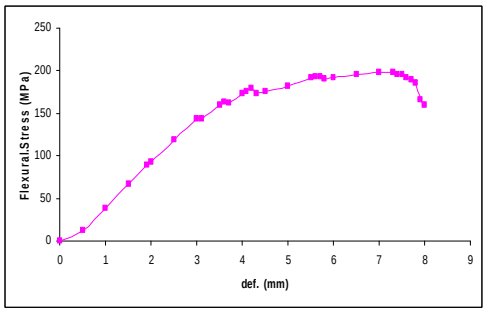

Figure (4) flexural stress -deflection curve for3G/EP

Fig.(5,6,7) show that the flexural stress-deflection curves for epoxy reinforcement by different kind hybrid composite according to the results shown in tables(2) the mechanical behavior between the glass and hybrid composites may be due to the differences in the mode of load transfer at the fiber - matrix interface and, consequently, in the interfacial bond strength and who fiber can be interlaminate layers in composite , the sample which reinforced (Kevlar - regular glass – Kevlar) characterized the highest bending (8mm). The less bending reinforced sample was (regular glass-Kevlar- regular glass) (4.5mm) even it less than the reinforced sample (Kevlar - regular glass – Kevlar), than that was enhanced through the microscopic test

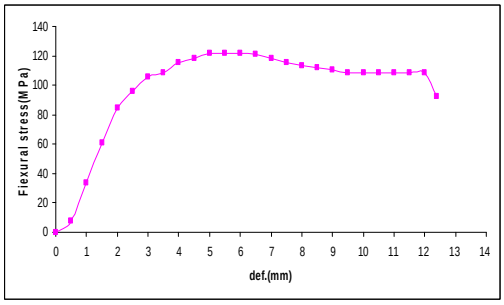

Figure (5) flexural stress -deflection curve for 3KGRK/EP

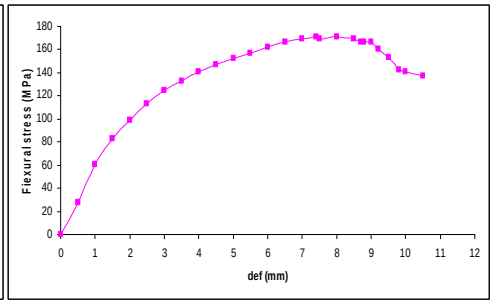

Figure (6) flexural stress-deflection curve for 3KGK/EP

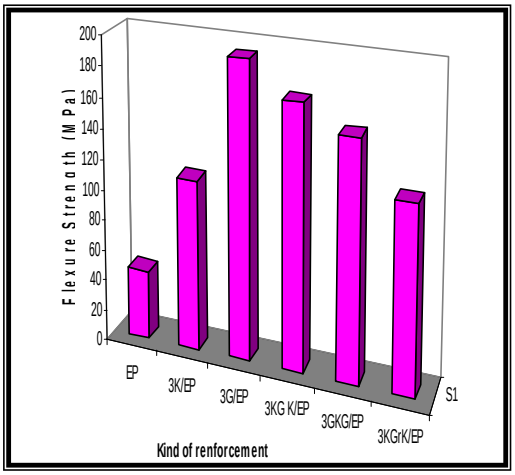

Figure (7) flexural stress -deflection curve for3 KGRK/EP

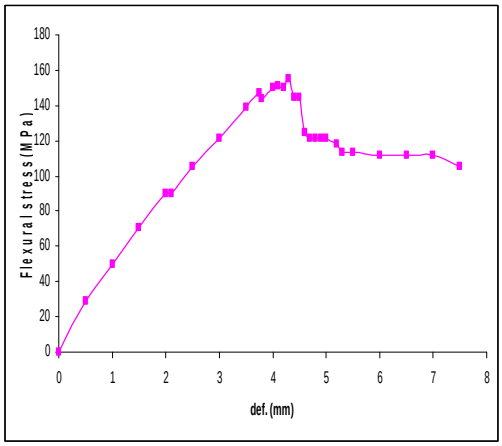

Figure (8) Effect of the reinforcement on flexural strength of samples

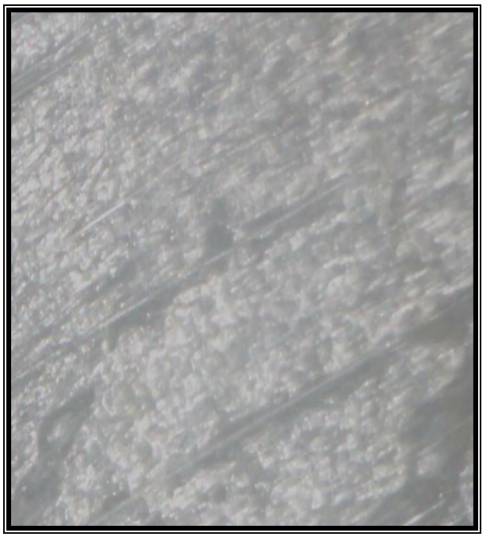

Figure (9) Buckling and fibrillation of fiber in local yielding

Figure (10) A single pull-out of E-glass-fiber from its matrix after deflection Loading

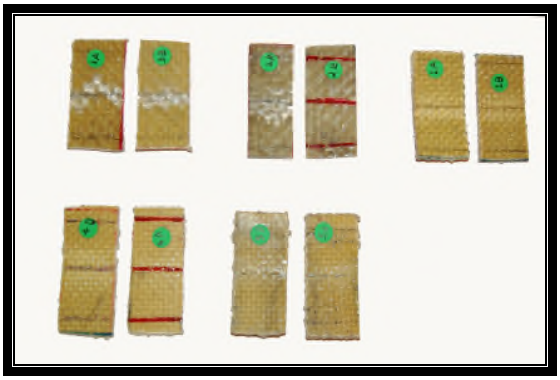

Figure (11) Photographic picture show the fracture surface of all samples

CONCLUSIONS

The following conclusions are dragged from the experimental investigations

1- The Kevlar fiber and glass fiber reinforced hybrid composites have positive effect as material reinforcement, because improve bending resistance.

2- Non –reinforced pure Epoxy has lower flexural resistance than (glass & Kevlar) fibers and hybrid composites .

3- The flexural strength, Young's Modulus and yield point of (3G/EP) higher than (3K/EP)

4- Bending test result shows that the sample which reinforced (Kevlar - regular glass - Kevlar) characterized the highest bending (8mm).

5- The less bending reinforced sample was (regular glass-Kevlar- regular glass) (4.5mm) even it less than the reinforced sample (Kevlar - regular glass – Kevlar), than that was enhanced through the microscopic test .

6- The sample (3KGK/EP) the best of hybrid .

REFERENCES

[1] Patil Deogonda, Vijaykumar N Chalwa" Mechanical Property of Glass Fiber Reinforcement Epoxy Composite" International Journal of Scientific Engineering and Research (IJSER) Volume1 Issue 4, December 2013 .

[2] Prashanth Banakar1, *, H.K. Shivananda2 and H.B. Niranjan3," Influence of Fiber Orientation and Thicknesson Tensile Properties of Laminated Polymer Composite", Int. J. Pure Appl. Sci. Technol., 9(1) (2012)

[3]T.D. Jagannatha and G. Harish" Influence of Carbon & Glass Fiber Reinforcements on Flexural Strength of Epoxy Matrix Polymer Hybrid Composites" T.D Int. Journal of Engineering Research and Applications, Vol. 5, Issue 4, (Part -7) April 2015 .

[4]Chensong Dong and Ian J. Davies, Optimal Design for the flexural behavior of glass and carbon fiber reinforced polymer hybrid composites, Materials Design, Vol. 37, 2012.

[5]K.G. Satish, B. Siddeswarappa and K. Mohamed Kaleemulla; Characterization of in-plane mechanical properties of laminated hybrid composites, Journal of Miner Mat Char Eng, Vol.9 (2), 2010 .

[6] Awham Mohammed Hameed "Development and Study of Blended- Base Polymer Composite" Ph. D. Thesis, University of Technology, Iraq , (2006).
[7] 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.
[8] James F. Shackelford , " Introduction Material Science For Engineers" University of Califon by Peason Enduction , (2009).
[9] Jadah A., "Investigation of some mechanical properties of sawdust and chopped reeds/UPE composite", M.Sc., Baghdad University, 2011
[10] Yong X. Gan " Effect of Interface Structure on Mechanical Properties of Advanced Composite Materials " International Journal of Molecular Sciences, Vol 10 , (2009) .
[11] Y. Menail, A. El Mahi, M. Assarar, B. Redjel, A. Kondratas" The effects of water aging on the mechanical properties of glass-fiber and kevlar-fiber epoxy composite materials" ISSN 1392 - 1207. MECHANIKA. (2009).