EFFECT OF KEVLAR FIBERS ON THE MECHANICAL BEHAVIOR FOR SOME OF EPOXY CHOPPED CARBON FIBER COMPOSITES

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Abstract

This research has been done by reinforcing the matrix (epoxy) resin with two kinds of the reinforcement.
One volume fractions was used (30%), Epoxy reinforced with chopped carbon fiber with and second reinforcement was epoxy reinforced with hybrid reinforcements which was the three laminates Kevlar fiber and chopped carbon fibers. After preparation of composite materials some of the mechanical properties have been studied of samples preparation. They were Tensile strength test, flexural strength test, Impact test, and Brinell hardness test
The studied show the tensile strength, flexural strength, shear stress and impact strength of the hybried composites values were increased with existence of Kevlar fibers, while the hardness was decrease. But the reinforcement with carbon fibers increases the hardness and decreases other tests.

تأثير ألياف الكفلر على السلوك الميكانيكي لبعض متراكبات الايبوكسي– الياف الكاربون المقطعة

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الخلاصة

في هذا البحث تم تدعيم المادة الاساس وهي الايبوكسي بنوعيين من التدعيم. الاولى تدعيم الايبوكسي مع الياف الكربون المقطعة بكسر حجمي ٣٠%. الثانية بتدعيم الايبوكسي تدعيم هجين وذلك باضافة طبقات من الياف الكفلر مع الياف الكاربون المقطعة مع الحفاظ على الكسر الحجمي ثابتا، وتم دراسة بعض الخصائص الميكانيكية لنماذج المتراكبات المحضرة، اذ تم أجراء أختبار الشد وأختبار الانحناء وأختبار الصدمة وأختبار صلادة برينل.
قد تبين من خلال الدراسة أن قيم متانة الشد، متانة الانحناء، أجهاد القص، متانة الصدمة تزداد مع وجود الياف الكفلر (المتراكب الهجين) بينما تقل الصلادة بوجود الياف الكفلر على خلاف التدعيم بالياف الكاربون حيث تزداد الصلادة وتقل الأختبارات الأخرى.

Introduction

Over the past few decades, polymers have replaced many of the conventional metals/ materials in various applications. This is possible because of the advantage of polymers offer over conventional materials. The most important advantages of using polymers are the ease of processing, productivity and cost reduction. Collectively, polymer composites are lightweight stiff, strong. The light weights of these composites also increase the energy efficiency for machine and transportation [1].

Hybrid composites which combine two or more different fibers in a common matrix, greatly expand the range of properties that can be achieved with advanced composites.

Hybrid have unique features that can be used to meet diverse and competing design requirements in a more cost-effective way than either advanced or conventional composites. Some of the specific advantages of hybrids over conventional composites are blanced strength and stiffness, blanced bending and membranes mechanical properties, reduced weight and/or cost, improved fracture toughness and improved impact resistance [2].

Fibrous materials such as glass-fiber and carbon-fiber have been widely applied as fillers in composites. In particular, aramid-fiber is widely used in automobile industry due to many impressive mechanical properties, for instance, light-weight, high specific modulus and strength, high thermal resistance and chemical inertness. It is known that the relatively weak mechanical properties of monolithic epoxy have limited its applications in components which demand high mechanical strength. Therefore, many research works on reinforcing polymer-based materials have incorporated various particle/whisker-type fillers to gain an insight into the way to solve the problem [3].

The most function of the fibers in a composite is to carry most of the load applied to the composite and provide stiffness. For this reason, fiber materials have high tensile strength and high elastic modulus. The continuous fibers give the highest tensile strength and tensile modulus composite but with a high directionality of properties. Randomly orientated short fibers do not lead to this directionality of properties but do not give such strength and tensile modulus [4]. The unidirectional alignment results in an anisotropic property profile- high strength and high stiffness in fiber orientation direction and sometimes comparatively poor mechanical behavior perpendicular to the fiber axis.

The matrix holds the fibers together. A loose bundle of fibers wouldn't be of much use. Also, though fibers are strong, they can be brittle. The matrix can absorb energy by deforming under stress. This is to say, the matrix adds toughness to the composite. And finally, while fibers have good tensile strength (that is, they're strong when you pull on them), they usually have awful compressional strength. That is, they buckle when you squash them. The matrix gives compressional strength to the composite. [5]

Charpy impact test was used to measure the impact strength, which may be defined as toughness or ability of material to absorb energy during plastic deformation. [6]

The flexural strength is defined as the materials are in the forms of beams and bent by three-point bending. [4]

The tensile test is one of the most widely used of the mechanical tests. Tensile test measure the resistance of a material to a static or slowly applied force [7]

Hardness is a measure of materials resistance to localized plastic deformation. Hardness test are performed more frequently than any other mechanical test for several reasons, it is simple and inexpensive, nondestructive, and other mechanical properties often may be estimates from hardness data such as tensile test [8].

Experimental Part

Preparation of composite

Composite was made using a stainless steel mould having dimensions {25x25x1}cm^3. The composites were prepared with one volume fraction of chopped carbon fibers (30%V_f). The ratio of hardener which was added to epoxy is 1:3, every 3 gm from epoxy resin adding 1 gm hardener, then mixed the solution very well before poured it to obtain homogeneity.

The chopped carbon fibers were mixed with resin then put in mould. This process repeated with another second hybrid composite. Three laminates of Kevlar fiber (49) have been added to the mould and the resin poured on to fibers .The mould left for 48 hour to get solid samples. Then the mould was heated for 50 ˚C for 3 hour to complete the curing process, the production samples have been cut out to obtain specimens of testing that agree with (ISO) or (ASTM) standards.(see figure 2)

The volume fraction can be calculated from the following equation:

$$\Phi = \frac{1}{1+\frac{1-\Psi}{\Psi}\frac{\rho_f}{\rho_m}} \quad \ldots\ldots\ldots\ldots\ldots (7)$$

Where:

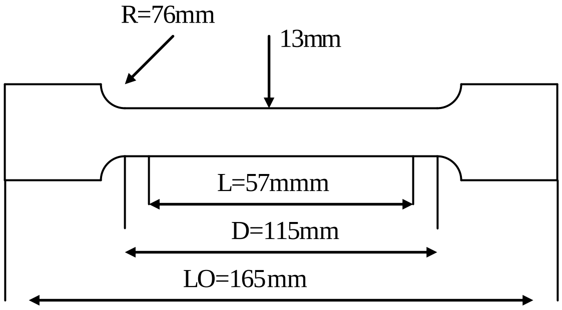
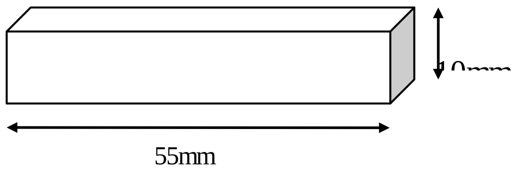
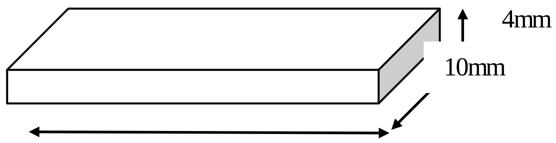
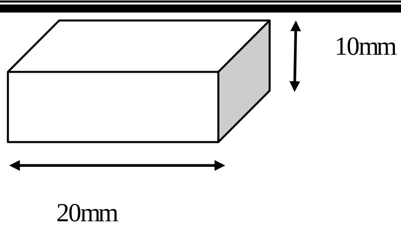
Φ : is the volume fraction of fibers.

Ψ : is the weight fraction of fibers.

ρ_f : is the density of fibers

ρ_m: is the density of matrix

Table 1: The standards of specimens for mechanical tests.

<table>
<tr><th>Test</th><th>Standard dimensions of specimen</th><th>Standards</th></tr>
<tr><td>Tensile strength</td><td></td><td>ASTM –D638M</td></tr>
<tr><td>Impact strength</td><td></td><td>ISO-179</td></tr>
<tr><td>flexural strength</td><td></td><td>ANSI/ASTM-D790</td></tr>
<tr><td>Brinell Hardness</td><td></td><td>ASTM-E10</td></tr>
</table>

Measurements

In this work Charpy impact test was used. The dimensions of specimens, width and thickness were measured and recorded, see table 2. The test was carried out in accordance with ISO-179. The impact strength (I.S) value was calculated by dividing the energy in KJ recorded on tester by cross sectional area of specimen.

I.S = fracture energy / cross sectional area for the specimen ----- (1) KJ/m^2

Table 2: The results for the samples of mechanical test

Specimens	Impact Strength KJ/m^2	Flexural Strength MPa	Shear Stress MPa	Ultimate Tensile Strength (MPa)	Young's Modulus (MPa)	Brinell Number
Composite	14.48	981.611	19.18	14.420	1215.7	207.58
Hybrid composite	٤٥.٤٥	1038.41	22.65	٩٦.١٥٠	866.4	109.98

Flexural (bending) test was used in this work. The dimensions and thickness of specimen were measured and recorded. The flexural strengths were calculated from the maximum stresses failure. The test was carried out in accordance with ASTM D-790. The flexural strength (F.S.) and shear stress (τ) were calculated from the following relationships:

$$F.S. = 3PS/ 2bt^2 \ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where: F.S: Flexural strength P: applied force till the failure of specimen occurs
S: Span, b: width of specimen, t: thickness of specimen

$$\tau = 3P/4bt \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where: τ: shear stress

The tensile test was used in this work. The length of specimen is 57mm.The thickness and width were measured and recorded. Tensile load is applied at a rate 1 ton.The velocity of pulling is 1 mm/min and by utilization of the connected graphic plotter, the relation of p–l is obtained. This relationship would be modified to relation of stress-strain curve to calculate the ultimate tensile strength (UTS) for the specimens. The test was carried out in accordance with ASTM – D638M.The maximum (peak) load (Fmax) was recorded. Ultimate tensile strength (UTS) was calculated from the following relationships:

$$\sigma = P / A \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where: P: load (N), A: cross sectional area

$$\varepsilon = \Delta L/L \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where ε : Strain, ΔL: length change, L: original length

$$E = Stress/Strain$$

Where E: Modulus of elasticity.

The Brinell hardness test was used in this work. The dimensions of specimen were measured and recorded. The test was carried out in accordance with ASTM-E10.
This device contains a digital vernier. In Haydrolic piston test it can be supplied with a special ball, the size of the ball most commonly used is (5 mm) which is used to stick into the specimen and the diameter of impression can be found with a special microscope. Microscpe is graduated in millimeter. The Brinell hardness number BHN can be found from the formula:

$$BHN = P/ \{(\pi(D/2))*\{D-(D^2-d^2)^{1/2}\} \ldots..(6)$$

Where:
P: is applied force in Kilograms, D ball indenter diameter in millimeters
d: diameter of impression in millimeters

Results and Discussion

1) Impact test

The Charpy impact strength of hybrid Kevlar/carbon fibers reinforced epoxy composite are higher than the results of composite reinforced with carbon fibers this can be seen in the table 2. The presence of Kevlar fibers in hybrid composite increase the impact strength of samples because that fibers resist shattering upon impact and the inhibits propagation of cracks [2].
In general, an increase in fracture energy was accompanied by increasing fiber toughness [9]. Toughness of the Kevlar fiber composite is significantly higher than that of boron or graphite composites. Furthermore, the very low density of the fibers provides a higher specific strength than glass, boron, or graphite reinforcing fibers [2].
Almeida .et al. (2003), showed that. Fiber composites (carbon, Kevlar and glass fibers reinforced with resin matrix) have a unique interaction with the externally applied load (impact loading), since severe internal damage can be generated without any external sign. In fact, several damage mechanisms can be operative, viz. matrix cracking, fiber breakage, fiber-matrix interface rupture and delamination; Moreover they found Kevlar fiber composites are recognized as one of the best materials against ballistic impact, were wave propagation governs the whole impact event. Also, they noticed that carbon fiber was stiffer and more resistant will support and redistribute better the applied load, postponing the propagation of defect [10].

2) Flexural Strength test

The three – point flexure test is one of the most popular mechanical tests.
The flexural strength is usually higher than the strength obtained in tensile test [11].
The results of flexural strength of hybrid composite (Kevlar / carbon fibers / epoxy composite) is higher than the composite (carbon fiber/epoxy). These results can be explained due to Kevlar fibers surface bond well with epoxy resins {For this reason, sometimes an epoxy-based is applied to Kevlar fibers before incorporating them in other polymer matrices}. Carbon fibers are also generally chemically inert; that is, interfacial interactions in carbon-fiber-based composites would be rather weak [12].

Wan et al., have prepare 3-D carbon /Kevlar /epoxy composites with various carbon to Kevlar fiber volume ratios The flexural, impact properties of the 3-D braided hybrid composites were measured in order to investigate the effect of carbon to Kevlar ratio and evaluate hybrid effects. The absorbed energy and flexural strength retention of the 3-D braided hybrid composites were found to decrease with relative carbon fiber content [13].

3) Tensile test

The tensile test is one of the most widely used of the mechanical tests.

Figure 3 shows the stress- strain curves of composite reinforced with carbon fibers and hybrid composite reinforced with carbon and Kevlar fibers

The ultimate tensile strength of the hybrid composite reinforced with Kevlar and chopped carbon fibers is highest than the composite reinforced with carbon fiber, see table 2.

The Kevlar fibers have the highest tensile strength than chopped carbon fibers because the continuous fibers give the highest tensile strength but with high directionality of properties .while randomly oriented short fibers do not lead to this in directionality of properties but do not give such high strength [4]. Despite the superlative tensile strength of this fiber; it possesses a comparatively low compressive strength due to its highly linear and regular microstructure [14]. Moreover; in the tension the loads are carried by the covalent bonds but in compression the weak hydrogen bonding and van der Waal force mean that local yielding and fibrillation can occur.[15]

4) Hardness test

The sample of composite reinforced with carbon fiber has highest value of Brinell number as compared with sample of hybrid composite reinforced with Kevlar and carbon fibers see table 1. The situation can be explained by the plastic nature (plastic deformation) of the Kevlar fiber which decreases hardness. [16].

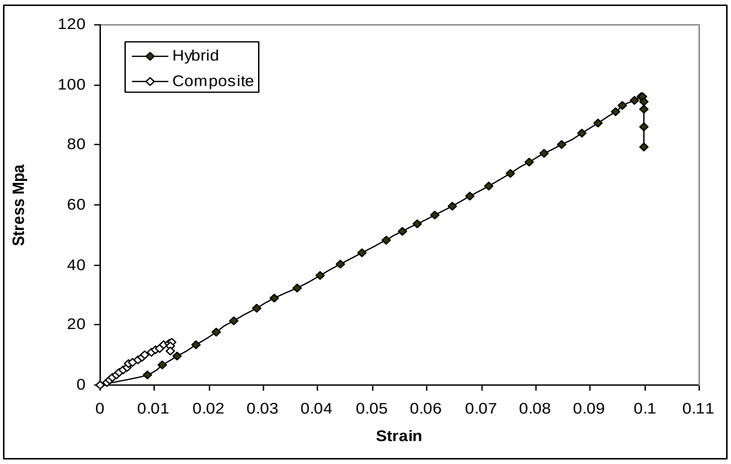


Figure 1: Show Stress-Strain of composite reinforced with carbon and hybrid composite reinforced with carbon/ Kevlar fibers

The following specimens have been obtained:

Figure 2:Samples of flexural, impact and tensile test (a) before and (b) after tests

Conclusion

1) The sample of hybrid composite reinforced with carbon \Kevlar fibers have a higher value of impact strength than sample of composite reinforced with carbon fibers because of existence of Kevlar fibers in hybrid composite which have a higher strength and impact resistance.
2) Flexural strength results show that the hybrid composite (epoxy reinforced with carbon and Kevlar fibers) have a higher value than the sample of epoxy chopped carbon fiber composite as Kevlar fibers have a good adhesion (bonding) with epoxy than carbon fibers
3) Results of hardness test show that hybrid composite have a lower value of Brinell number composite (epoxy chopped carbon fibers composite). In generally the hardness decreases with increases of materials elasticity.
4) The tensile stress has substantially increase in sample of hybrid composite epoxy reinforced with carbon and Kevlar fibers than sample of composite epoxy reinforced with carbon fibers. Because Kevlar fiber was continuous fibers which have high tensile strength and tensile modulus than chopped carbon fibers which have random arranged

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