Effect ofweight percentage chopped carbon fibers on the mechanism of cracks propagation for Epoxy composites

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Abstract

In this research, the mechanism of cracks propagation for epoxy/ chopped carbon fibers composites have been investigated .Carbon fibers (5%, 10%, 15%, and 20%) by weight were used to reinforce epoxy resin. Bending test was carried out to evaluate the flexural strength in order to explain the mechanism of cracks propagation. It was found that, the flexural strength will increase with increasing the percentage weight for carbon fibers. At low stresses, the cracks will state at the lower surface for the specimen. Increasing the stresses will accelerate the speed of cracks until fracture accorded .The path of cracks is changed according to the distributions of carbon fibers

Keywords

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تأثير النسب الوزنية لالياف الكاربون المقطعة على ميكانيكية انتشار الشقوق لمتراكبات الايبوكسي

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الخلاصة:

درس في هذا البحث ميكانيكية انتشار الشقوق لمتراكبات الايبوكسي بعد اضافة نسب وزنية من الياف الكاربون المقطعة (5%و10%و15%و20%) لراتنج الايبوكسي وفحصت العينات بفحص الانثناء ثلاثي النقاط وحسب من خلاله متانة الانثناء وميكانيكية انتشار الشقوق لقد وجد ان متانة الانثناء تزداد بزيادة النسب الوزنية للالياف وبتقليل الاجهاد الشقوق تستقر في السطح السفلي للعينة وبزيادة الاجهاد تتعجل سرعة الشقوق وتصل الى الكسر ان مسار الشقوق يتغير تبعا لتوزيع الالياف في المادة المتراكبة .

Introduction

Thermoset materials are highly cross-linked polymers with a three-dimensional molecular structure. The network structure gives rise to high stiffness, high strength, and good heat and solvent resistance, which make thermosets to be frequently used as structure materials. The network structure also results in a major drawback of thermosets poor resistance to impact and crack initiation. Therefore, many efforts have been made to improve the fracture toughness of thermosets while still maintaining their other desirable properties.

Epoxy resins are among the strongest thermosets and are the most extensively used class of thermosets in structural applications. Consequently, most investigations on the toughening of thermosets have mainly focused on epoxy systems [1].

Energy of fracture is defined as the average resistance to the propagation of cracks through a material [2].

Crack stability when the fracture occur when cracks propagate inside the structure of materials to produce new surface.The behavior of crack propagation depends on materials toughness[3] and the test conduction. Crack propagation is considered to be unstable when a precipitous load drop is displayed at fracture and the crack accelerates quickly.[4] In stable crack propagation the crack velocity is low and propagation may be visually tracked.some time mixture of stable and unstable cracking occurs together in the same test when sawtooth are produced,[5]

Purslow[6] described the origin and development of fractographic feature found in the matrix of carbon fiber-reinforced epoxy composites and their signification in the analysis of the failure of structures fabricated from composite material.

Piggot[7] studied the parameters covering on stress-strain curves in short fiber-reinforced polymer It was shown that the shape of the stress-strain curves is strongly dependent on the fiber aspect ratio, wile being relatively little affected by the adhesion between fibers and matrix. Fracture mechanisms in series of short fiber-reinfoced fiber thermoplastic made with controlled fiber orientation were investigated by Blumentritt et .al [8] They concluded that short fiber- reinforced thermoplastics fracture primarily by fibers pulling out of the matrix material in both, Ductile and brittle composites.Cracks were apparently initiated at structural defects such as misaligned fibers and fibers end. The cracks then propagate through the matrix near the interface to produce composite fracture.

Theocaris[9]studied the modes of crack propagation, as well as the fracture surface of carbon fiber- reinforced composites by means of a Scanning Electron Microscope (SEM).

The composite specimens used were composed of an epoxy polymer matrix reinforced with Unidirectional carbon fibers.

Jia Yu,YiZhno Liu,Rong RongShi[10] observed that the fiber volume fraction are stretched Dynamically under static load in SEM, initiation and propagation mechanism of crack is in-situ Observed and tensile fracture of specimens. The results show that: microscopic cracks are mainly originated from fracture of fibre, numerous fibre cracks transfixion each other in form of matrix or interface cracking, and cause failure of CFRP. Microscopic crack propagation path is related to the thickness of matrix layer between fibres. Propagation of single fibre crack at interface accord with description of microscopic crack deflection criterion for fibre reinforced composite, but the crack deflection criterion cannot descript microscopic crack propagation mechanism of unidirectional CFRP effectively, because distribution discreteness of fibre and its strength are not considered.

The aims of this work: - were to study the mechanism of cracks propagation for composite, under direct load perpendicular to the fibers.

Experimental work

1- Materials

1-<u>1 Epoxy resin</u>

Epoxy resin was used as a matrix (Master top 1210 plus), adhesive grade room temperature supplied by Iranian BASF construction chemical. The ratio of hardener to epoxy used in this study are approximately [1:2] .

1-2<u>Carbon fibers:-</u>

Carbon fibers were used in this study to reinforce the epoxy which were supplied by Grazer Company Germany. The length of carbon fibers (short) 1-2 Cm,fiber diameter 7-8 µm,and with density 1.75gm/cm^3 .

2-Sample preparation:-

Hand Lay-up technique was used to prepare sheets of composites. amount of Epoxy was mixed with carbon fiber in different weight percentage (5%, 10%, 15%, 20%) by weight and the samples, were cut the sample according to international specifical ASTM D790 standards.

Figure [1]photograph show the bending specimen shape

3-Bending Test

Three point bending test was used to investeged the mechanism of crack propagation.Instron 1122 was used and the cross head speed were fixed(1mm/min).load- deflection curves were obtained for different samples.the support span (distance between the support) was depending on the specimen thickness,the load was applied on a specimen at the middle of support span.

Flexural strength

Also known as modulus of rupture, bend strength, or fracture strength, is defined as a material's ability to resist deformation under load. It is measured in terms of stress, and thus is expressed in units of pressure (or stress, the two being equivalent). The value represents the highest stress experienced within the material at its moment of rupture. In a bending test, the highest stress is reached on the surface of the sample.[11]

For a rectangular sample under a load in a three-point bending setup:,

$$F.S = 3PL/2bd^2 , \quad E_B = ML^3/4bd^3$$

P:- is the applied load (N) at the highest point
of load-deflection curve.
L :- is the span length .
b :- is the width of test specimens.
d:- is the thickness of test specimens.
M:-is the line of curve load-deflection

Results and Discussion

In flexure test,the specimen effects by two mode of test.the convex side of the specimen are extended and concave side is compressed with an unstrained neutral axis through the center.

Two factor were dominate which effect on the values of flexure modulus of composites, the flexure strength of matrix, and the adhesion between fibers and matrix.[12]

At 5% Percentage of chopped carbon fiber, at low stress the specimen will be take convex shape, so that the primary cracks will form at the middle of the specimen .At the maximum stress the cracks will spread and the stress field to minimum values figure (2) , The cracks will propagate very fast perpendicular to the fibers.

For 10% percentage of carbon fibers, the maximum stress will increases and the material become more rigged because there are increasing in value for flexural modulus (Table 1) figure (3) shows that ,after the stress reach maximum value, The stress would decrease gradually until fracture occur ,That means that cracks could not be spread fast because the fibers would restricted and deflected the cracks.

The same mechanism was found at15% and 20% percentage of carbon fibers ,but from figure (4)(5) The curves could explain the mechanism for cracks propagation ,specially at 20% percentage of carbon fibers .The cracks would spread step by step and deflected parallel to the surface of specimen .The values of maximum flexural stress and flexural modulus will decrease (Table1) From There curves, we can conclude That the mechanism of cracks propagation ,may be take different types, due to the specification for fibers, interfaces and types of matrix .our model which can explain the behavior for cracks propagation was That ,the fibers have good adhesion with matrix, and The specimen was loaded, The energy which absorbed by composite will transform to kinetic energy for cracks, many phenomena may be observed such that ,of the absorbed energy is greater The cohesion energy, the fibers will cut and the cracks will grow towards to the second fibers and so on .The second behavior that if the cracks could not be able to cut fibers, The cracks will deflect and propagate in interfaces until fracture accour.figure(6).

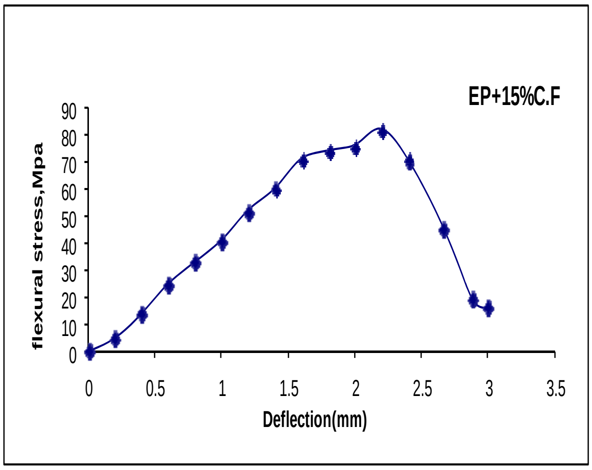

Figure (4) Flexural stress curve for EP Composites at 15%

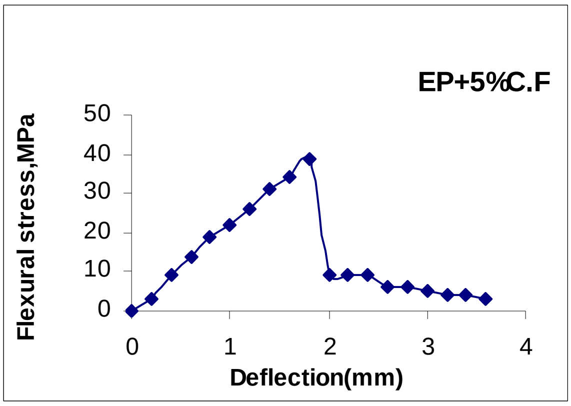

Figure (2) Flexural stress curve for EP Composites at 5%

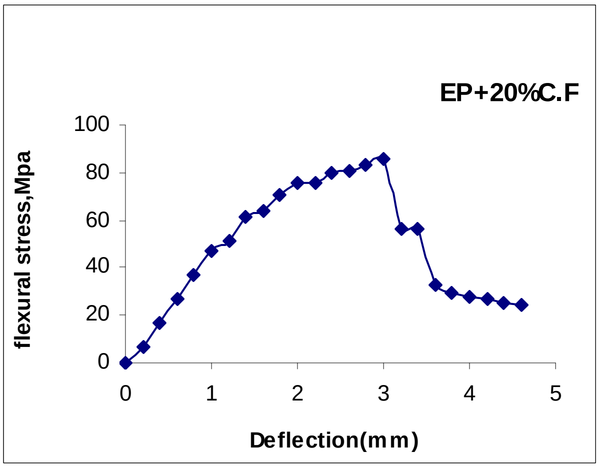

Figure (5) Flexural stress curve for EP Composites at 20%

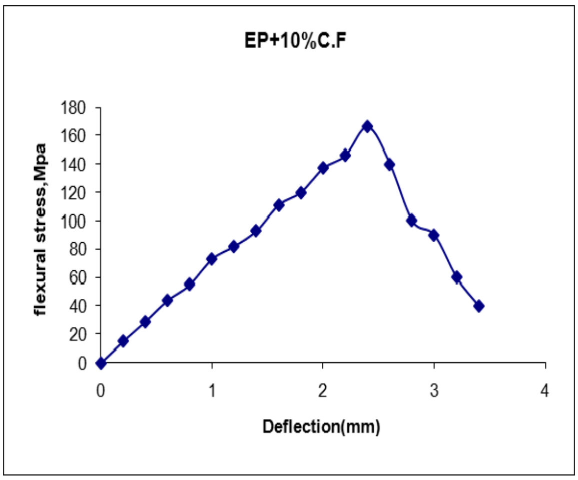

Figure (3) Flexural stress curve for EP Composites at 10%

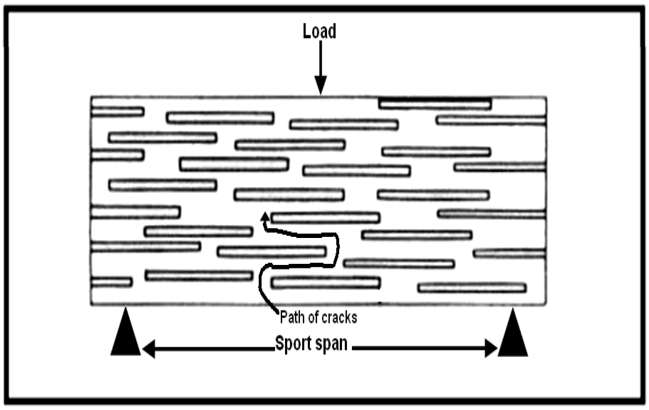

Figure (6) the composite material reinforced with short fibers

***Table (1) Values of Flexural modulus, Maximum deflection at Max.stress for Epoxy composites*.**

Specimen Type	Max.flexural stress(MPa)	Max.defection At max. stress(mm)	Flexural Modulus E(GPa)
EP+5%C.F	39	1.8	3.04
EP+10% C.F	166	2.8	10.96
EP+15% C.F	82	2.2	6.44
EP+20% C.F	86	3.0	7.27

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