Study of Tensile Strength and Hardness Property for Epoxy Reinforced With Glass Fiber Layers

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Abstract

Tensile strength and hardness property were studied in an epoxy (DGEBA) resin as a matrix reinforced with glass fibers for different volume fraction as layers.

A comparison was done between woven roven samples, random layers samples and sandwich composite samples which consists of (woven roven and random). Finally the results show that the sandwich composite gives higher tensile strength, while the composite reinforced with woven roven fiber has maximum hardness values.

Key words: Composite, Tensile mechanical properties.

دراسة مقاومة الشد وخاصية الصلادة لمتراكبات الايبوكسي المدعمة بطبقات من الالياف الزجاجية

الخلاصة

تم في هذا البحث دراسة مقاومة الشد وخاصية صلادة برينل لراتنج (DGEBA) المستخدم في هذا البحث كمادة اساس والمدعم بالياف زجاجية على شكل طبقات بنسب حجمية مختلفة.

تم اجراء مقارنة للنتائج بين المتراكبات المدعمة بالالياف الزجاجية (المتعامــدة والعشــوائية والمتوالفة). وقد اظهرت النتائج ان مقاومة الشد لمتراكبات الايبوكسي المتوالفة اي المدعمــة بالنوعين من الالياف تكون اعلى من المتراكبات المدعمة بالالياف المتعامدة والعشوائية.

كما اظهرت النتائج ان المتراكبات المدعمة بالالياف الزجاجية المتعامدة تمتلك صلادة اعلى من المتراكبات المدعمة بالانواع الاخرى.

Introduction

The composite material is a material that consist of two or more physically distinct phases, suitably arranged or distributed, the continuous phase is referred to as ,the matrix , while the distributed phase is called the reinforcement .

Three things determine the characteristics of a composite: the matrix, reinforcement and the interface between them.

Many reinforcement materials are available in a variety of forms: continuous fibers, short fibers, whiskers, particles, etc… [1]

The role of mixture always predicts the density of fiber-reinforced composites [2]

$$rc = Vmrm + Vfrf \quad \text{………. (1)}$$

$$Vm = 1 - Vf \quad \text{………… (2)}$$

$$Vf = \frac{1}{1 + \frac{1 - yr\ f}{yr\ m}} \quad \text{…….. (3)}$$

where

rc : density of the composite

rm : density of the matrix

rf : density of the fibers

Vm : volume fraction of the matrix

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Vf : volume fraction of the fibers
y : weight fraction of the fibers

The tensile strength of a fiber-reinforced composite (Tsc) depends on the bonding between the fibers and the matrix.

The function of the matrix is to transfer the stresses to the load-bearing fibers [3]

$$Tsc = Vf sf + Vm sm \quad \text{………… (4)}$$

where: -

Tsc: tensile strength of the composite.

sf : stress of the fibers
sm : stress of the matrix

The matrix supports the fibers and keeps them in the proper position transfers the load to the strong fibers, protects the fibers from damage during manufacturing and prevents cracks in the fiber from propagation [1, 3].

Although hardness testing does not directly give as much detailed information as does tensile testing, it is so fast and convenient that it is much more widely used.

Hardness is usually defined as resistance of a material to penetration and it is classified into three types: Rockwell, Brinell, and Vickers [4].

Epoxy:

Epoxy resin are those resins prepared from compounds containing an average of more than one epoxy group per molecule and capable of being converted through these groups to useful thermosetting products, Both the low molecule precursors and the cured product are known as reins [5].

The advantages of the epoxy resins are low shrinkage, high adhesive strength, outstanding chemical resistance, excellent electrical properties and excellent heat resistance [6].

<u>Fiber reinforcement</u>

Many factors must be considered when designing a fiber-reinforced composite such as:

1- Fiber length and diameter: the strength of a composite improves when the aspect ratio (L/D) is large, where L: fiber length and D is the diameter of the fiber.

2- Amount of fiber: the strength and stiffness of the composites increase with increasing the volume fraction till 60%, beyond that fibers can no longer completely surrounded by the matrix.

3- Orientation of fibers: the orientation of fibers has a great role in the strength of the composites.

One of the unique characteristics of fiber-reinforced composites is that their properties can be tailored to make different types of loading conditions [7].

<u>Experimental work</u>

Epoxy resin type (DGEBA) was used with its hardener in ratio (3:1), also two types of glass fibers were used for reinforcing the epoxy resin.

1- Glass chopped standard mat type (E-glass) with surface density of (0.277 Kg/m2).

2- Woven roven with angle of (0-90) continuous direction with surface density (0.5 Kg/m2)

Hand lay-up technique was used to prepare sheets of epoxy composites reinforced with two of glass fibers (random, Bidirectional and with the two types together as a sandwich).

The sheets were left to solidify at room temperature (23+2) C.

Epoxy composites with standard dimensions (ANSI / ASTM D 638)

for tensile strength test and (ASTM-E10) for brinell hardness test were prepared as shown Fig (1).
The brinell hardness test was used in this study, the law used to calculate brinell hardness was:-

$$HBr = \frac{0.102*2F}{pD(D-\sqrt{(D2-d2)}} \quad \text{……..} (5)$$

where:
F: applied load equal to (2000N).
D: diameter of the spherical indenter equal to (5mm).
d: diameter of the residual impression.

Result and discussion

The results in the Table (3) show that the tensile strength of the composite reinforced with (woven roven, random) fibers increased with increasing the numbers of layers because of the effect of orientation of fibers (distribution in the matrix) which has the major role in the mechanical behavior of the composite (Fig.2 &Fig.3).
It has been noticed that the tensile strength of the composite reinforced with woven roven fibers (15Cm) length, is higher than the composite reinforced with random fibers (5 Cm) length, because of the length and the alignment of fibers which leads to distribute the load on the length of fibers [8].
While in the composite reinforced with random fibers the load is concentrated at the end of short fibers and the alignment of fibers is randomly distributed in the matrix which make the control of transmission of the load from the matrix to the fibers through the interface region is weak [9].
While in (Fig.4) the sandwich composite has maximum tensile strength in comparison with the two other types for (3, 5, 7) layers because of increasing the volume fraction of fibers which leads to create high interface region between the fibers in different types and between the matrix and the fibers in the same sample making the transmission of the load from the matrix to the fibers through the interface region easily [10].
But for the (9) layers the tensile strength decreased because of the high value of volume fraction (56%) where the fibers are not surrounded by the matrix, therefore the reinforcing does not have any role in the matrix [7].
The result in the Table (4) show that the hardness property of the composite reinforced with the fibers increased with increasing the numbers of layers.
The mechanism of deformation process includes three steps, the first step is elastic deformation when the loads are applied to the surface of the samples through the spherical indenter, the second step over loading creates a significant plastic deformation, and the third step an exceeding a critical load for yielding, a small spherical impression remains on the surface of the samples [11].
It has been noticed that the Brinel hardness of the composites reinforced with woven roven fibers (Fig.5) is highes than the other types because of the alignment and the length of the fibers which lead to contribute the loads along the fibers making the step of elastic deformation long and exceeding a critical load for yielding not easy.
While in the composites reinforced with random fibers and sandwich composites (Fig.6 & Fig.7) failure of short fibers is a result of various microscopic failure mechanisms

associated with fibers, matrix and interface [12].

The mechanisms related to the fibers fractures which act as sites of stress concentration in the matrix inducing voids at fiber ends and rod-shaped micro cracks along the fibers; form an easy path for the crack tip and accelerate its propagation. In other words exceeding the critical loads may be easy for yielding therefore the hardness property is low [13].

Table (1): The Mechanical properties of the epoxy resin and glass fibers

Mechanical Property	Epoxy resin	E-glass fibers
Tensile Strength	26 N/mm2	350 N/mm2
Compression Strength	93 N/mm2	70 N/mm2
Young Modulus in Compression	63 N/mm2	7350 N/mm2

Table(2): Tensile strength for different types of composite theoretically according to equ. (4)

No. of layers	EP+ woven roven		EP + Random		EP + Sandwich	
	Tsc N/mm2	Vf	Tsc N/mm2	Vf	Tsc N/mm2	Vf
3	155.6	40	145.88	37	178.28	47
5	162.08	42	158.84	41	181.52	48
7	172.44	46	165.32	43	191.24	51
9	178.92	48	175.04	46	207.44	56

Table (3): Tensile strength for different types of composite experimentally

No. of layers	EP+ woven roven		EP + Random		EP + Sandwich	
	Tsc N/mm2	Vf	Tsc N/mm2	Vf	Tsc N/mm2	Vf
3	153.28	40	127.73	37	254.01	47
5	209.61	42	221.4	41	475.91	48
7	269.6	46	207.51	43	491.55	51
9	309.7	48	276.69	46	380	56

Table (4): Brinell hardness for different types of the composite

No. of layers	EP+ Woven roven		EP+ Random		EP+ Sandwich	
	HBr N/mm2	Vf	HBr N/mm2	Vf	HBr N/mm2	Vf
3	38.7	40	32.4	37	19.4	47
5	46.3	42	36.3	41	25.9	48
7	50.8	46	40.8	43	38.7	51
9	62.1	48	45.2	46	50.8	56

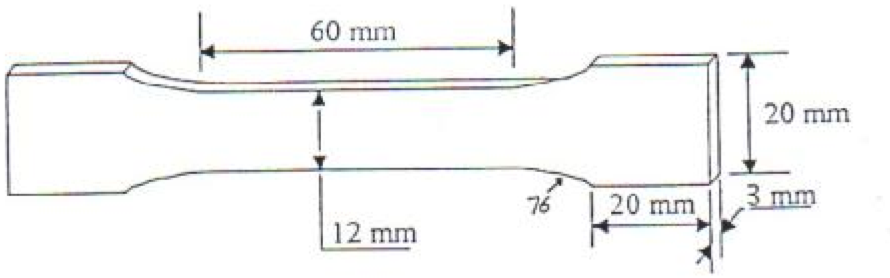

Fig. (1): Specimen Dimension of tensile test

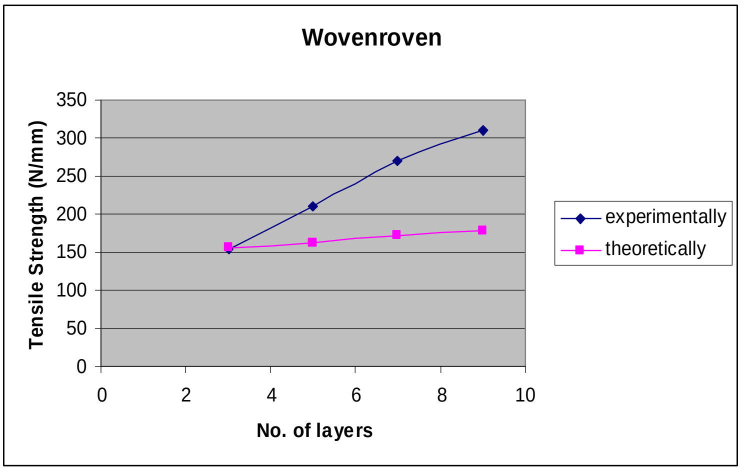

Fig. (2): Variation in the tensile strength with the No. of layers for the composite reinforced with woven roven glass fibers.

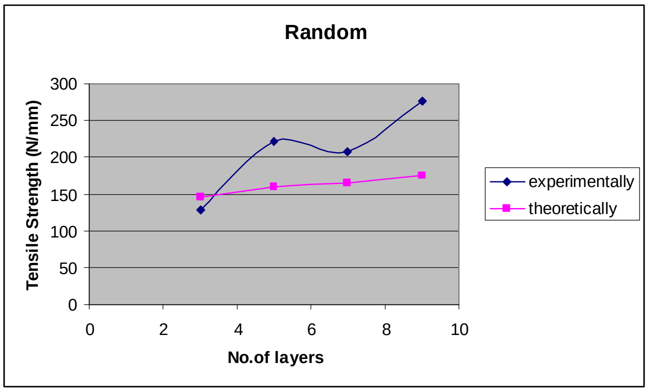

Fig. (3): Variation in the tensile strength with the No. of layers for the composite reinforced with random glass fibers.

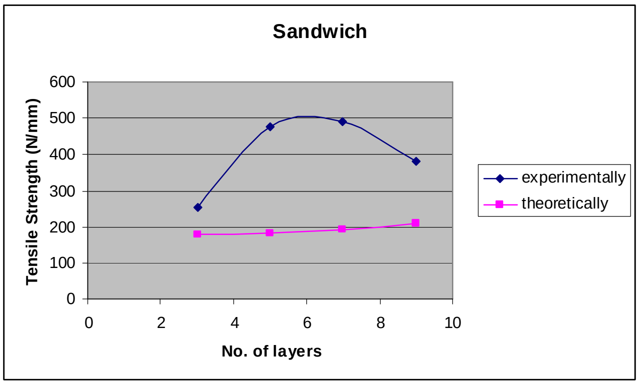

Fig. (4): Variation in the tensile strength with the No. of layers for the composite reinforced with sandwich glass fibers

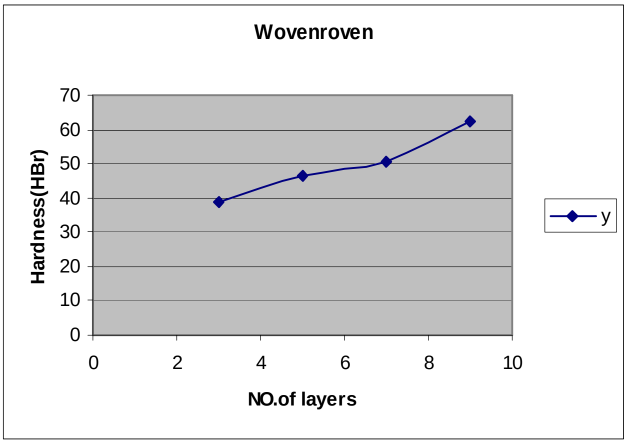

Fig. (5): Variation in the Brinell hardness with the No. of layers for the composite reinforced with woven roven glass fibers.

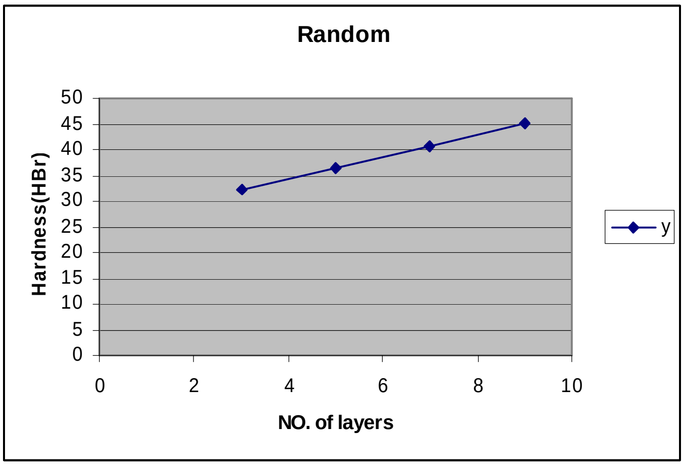

Fig. (6): Variation in the Brinell hardness with the No. of layers for the composite reinforced with random glass fibers.

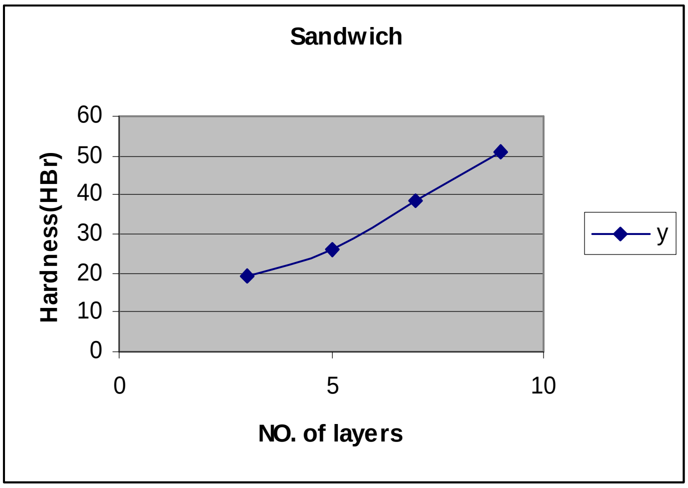

Fig. (7): Variation in the Brinell hardness with the No. of layers for the composite reinforced with sandwich glass fibers

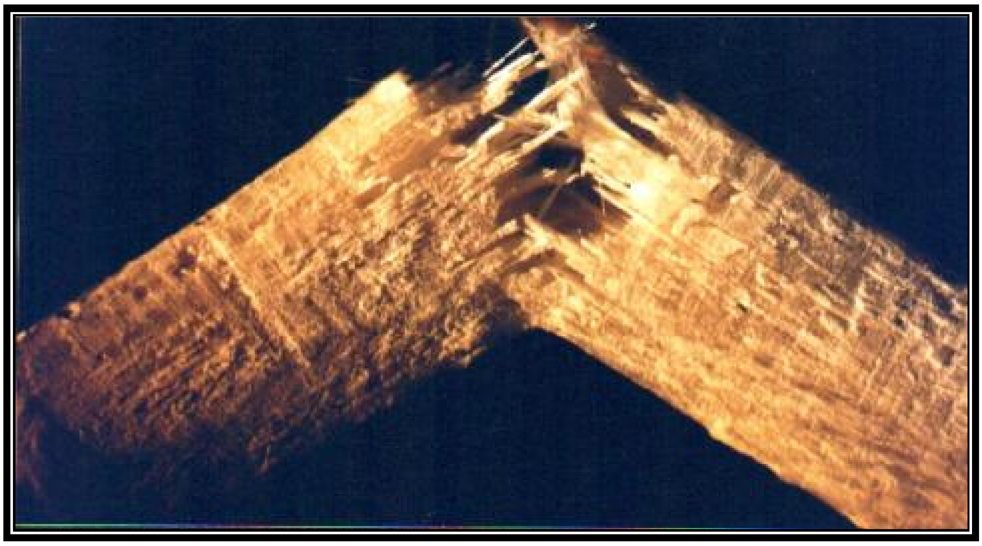

Fig (8.a): Tensile side of the fracture surface of the sample (Ep+ wovenroven)

Fig (8.b): Tensile side of the fracture surface of the sample (Ep+ random) 7 layers

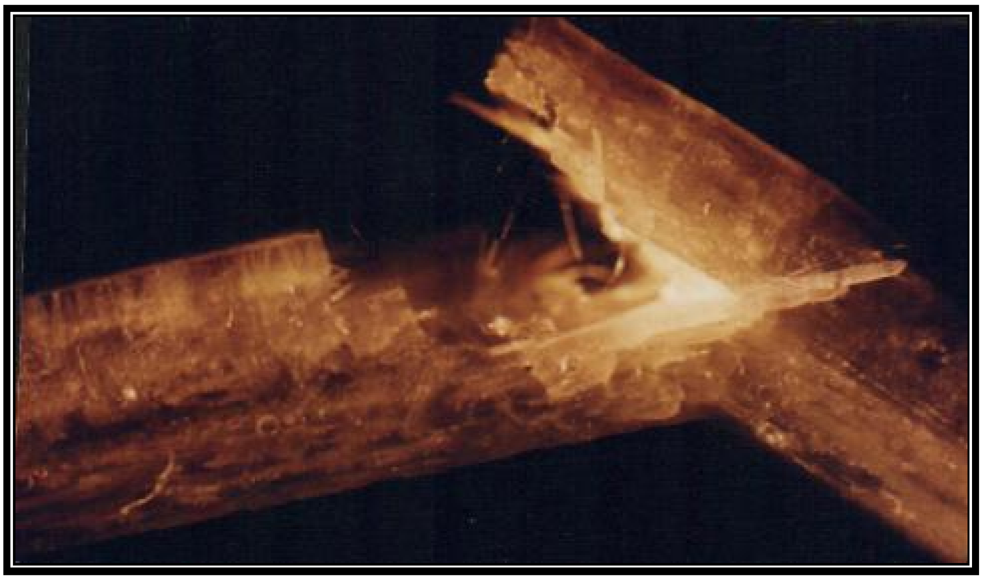

Fig (8.c): Tensile side of the fracture surface of the sample (Ep+ sandwich) 7 layers

Conclusion

From the results in the present work, it was found that depending on the number of layers, the specific failure load could be enhanced from a value of about 26 N/mm2 obtained for epoxy resin to 153 N/mm2 after reinforcing with woven roven glass fibers, while the failure tensile load changed to 127 N/mm2 after reinforcing with random glass fibers and finally it changed to 254 N/mm2 after reinforcing with the two types of the fibers as a sandwich, and in all the types the failure tensile load increased with increasing the number of layers except in sandwich composite when it decreased for a layers due to the high volume fraction.

The Brinell hardness of epoxy resin is about 30 N/mm2 and increased after reinforcing with glass fibers in all the types of composite with increasing the number of layers.

The maximum value of Brinell hardness was 62.1 N/mm2 for epoxy reinforced with (9 layers) of woven roven glass fibers in compare with the other types of composite.

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