Influence of Natural Fiber on the Mechanical Properties of Epoxy Composites

Noor Sabah Sadeq*

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Abstract

The present study deals with the effects of natural fibers on some mechanical properties of the Epoxy composite. This research was carried out by reinforcing the matrix (Epoxy) resin with natural material (cane sugar fibers) and synthetic fibers (chopped carbon fibers). The natural fibers were exposure to chemical treatment before reinforcement.

The hybrid composites contain of chopped carbon and cane sugar fibers is produced using hand lay method. Each sample was reinforced with different volume fraction such as 30%, 20%, and 10%. After preparation of composite material some of the mechanical properties flexural and impact tests were studied of prepared samples.

Cane sugar composite has the higher values (of flexural strength 490.77 MPa and of impact strength 93.92 KJ/m^2) than chopped carbon composites (flexural strength 93.19 MPa and impact strength 23.92 KJ/m^2). It was found that the additions of natural fibers (cane sugar) to chopped carbon fibers improve of the mechanical properties of hybrid composites.

تأثير الألياف الطبيعية على بعض الخصائص الميكانيكية لمتراكبات الأيبوكسي

الخلاصة

الدراسة الحالية تتعامل مع تأثير الالياف الطبيعية على بعض الخصائص الميكانيكية لمتراكبات الأيبوكسي. في هذا البحث تم تدعيم المادة الاساس الأيبوكسي مع مواد طبيعية(قصب السكر) و الياف صناعية (الياف الكاربون المقطعة) وقد تم تعريض الألياف الطبيعية الى معاملة كيميائية قبل التدعيم.

المتراكبات الهجينة احتوت على الياف الكاربون المقطعة والياف قصب السكر وأنتجت بطريقة الصب اليدوي.

جميع النماذج دعمت بكسور حجمية مختلفة(10%, 20%,30%,). بعد تصنيع المتراكبات , تم دراسة بعض الخصائص الميكانيكية للنماذج المحضرة وهي متانة الأنحناء (MPa) ومقاومة الصدمة (KJ/m^2)

متراكب قصب السكر امتلك اعلى قيم لمتانة الأنحناء 490.77 MPa و مقاومة الصدمة 93.92 KJ/m^2 بالنسبة لبقية متراكبات الياف الكاربون المقطعة. 93.19 MPa لمتانة الأنحناء و 23.92 KJ/m^2 لمقاومة الصدمة. وجد أن أضافة الألياف الطبيعية لالياف الكاربون المقطعةحسنت من الخصائص الميكانيكية للمتراكبات الهجينة.

* Applied Sciences Department, University of Technology/Baghdad

1. Introduction

The use of natural fibers in organic matrices is highly beneficial because the strength and toughness of the resulting composites are greater than those of the unreinforced materials. Moreover, lignocelluloses natural fibers are usually strong, light in weight, cheap, abundant and renewable. Over the past decade, natural fibers have found use as a potential resource for making low-cost composite materials. One difficulty that has prevented the use of natural fibers is the lack of good adhesion to polymeric matrices. In particular, the high moisture sorption capacity of natural fibers adversely affects adhesion with a hydrophobic matrix and, as result, it may caused material degradation and loss of strength.[1]

Natural fibers are considered as strong candidates to replace the conventional glass and carbon fibers. The chemical, mechanical, and physical properties of natural fibers have distinct properties; depending upon the cellulosic content of the fibers which varies from fiber to fiber. [2]

The properties of the fiber–matrix interface are of great importance for the macroscopic mechanical properties. Physical and chemical treatments can be used to optimize this interface, bearing in mind that the efficiency of fibers varies with the materials and the methods used. [3]

The physical properties of natural fibers are mainly determined by their chemical and physical composition, such as structure of fibers, cellulose content, angle of fibrils, and cross section, and by the degree of polymerization.[4]

The combination of a plastic matrix and reinforcing fibers gives rise to composites having the best properties of each component. The most commonly used are thermoset polymers such as polyester, epoxies and phenolics.[5]

Pavithran et al., they are determined the fracture energies for sisal-, pineapple-, banana- and coconut-fiber–polyester composites (fiber content of approximately 50 vol.%) in a Charpy-impact-test. They found out that, except the coconut-fiber–polyester composites, an increase in fracture energy was accompanied by an increasing fiber toughness (determined by the stress–strain diagram of the fibers). Natural fiber reinforced plastics with fibers which show a high spiral angle of the fibrils, indicated a higher composite-fracture-toughness than those with small spiral angles. That is why, according to Pavithran et al., composites with sisal fibers (spiral angle. 258) show an optimum of impact properties.[6]

Idicula et al., studied the mechanical performance of short randomly oriented banana and sisal hybrid fiber reinforced polyester composites with reference to the relative volume fraction of the two fibers at a constant total fiber loading of 0.40 volume fraction (V_f), keeping banana as the skin material and sisal as the core material. They found a positive hybrid effect was observed in the flexural strength and flexural modulus of the hybrid composites. The tensile strength of composites showed a positive hybrid effect when the relative volume fraction of the two fibers was varied and maximum tensile strength was found to be in the hybrid composite having ratio of banana and sisal 4:1. The impact strength of the composites was increased with increasing volume fraction of sisal. [4]

Tajvidi et al., studied the effect of natural fibers on thermal and mechanical properties. Composites of polypropylene and various natural fibers including kenaf fibers, wood flour, rice hulls and newsprint fibers were prepared at 25% and 50%(by weight) fiber content level. They studied dynamic mechanical properties and compared with the pure plastic. They found that natural fibers filled polypropylenes behave more elastically than their pure counterpart [7]

The main aim is to use the natural fibers like cane sugar that comes from nature without any kind of synthetic preparation; moreover to develop new composites using fibers and resins from renewable resources.

2-Experimental Methods:

2.1. Materials

The Epoxy resin (Quickmast 105) used as matrix. The density of Epoxy is 1.04gm/cm^3. Chopped carbon fibers (density is 1.06gm/cm^3) were obtained from local supplier and cane sugar fibers were kindly supplied from Egypt. The density of cane sugar fibers is (0.83 gm/cm^3).

2.2. Fibers treatment:

Cane Sugar fibers were cut into (11) cm length and (3) mm width. Before any composite production, natural fibers experienced chemical treatment .firstly fibers are immersed in water contain 3% NaOH solution for about 3 hours. Then the fibers are dried in oven at 60°C for 2 hours. The fibers were left for 24 hours to dry at room temperature before being used. [1]

Chemical treatment was used to improve the compatibility bonding between fiber and matrix

2.3. Preparation of composites:

Composite was made using a wood mould having dimensions (12.5x12.5) cm^2 length, width respectively. The composites were prepared by varying the relative volume fraction of fibers as shown in table (1). The ratio of hardener which was added to Epoxyr is (3:1), every 3 gm from Epoxy (1) gm hardener was added, then mixed the solution very well before poured it to obtain homogeneity.

The cane sugar fibers were put in mould and the resin poured onto fibers. That process repeated with another hybrid composite. The chopped carbon fibers were mixed with epoxy resin and hardener the half resin was poured onto the mould then put the cane sugar fibers then put other resin over the cane sugar fibers, see table{1}.The mould left for 24 hour to get solid samples. Then the mould was heated for 50˚C for 3 hours to complete the curing process.

2.4. Measurements

In this work 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. Toughness takes into account both the strength and ductility of the material [8]

The dimensions of specimens, width and thickness were measured and recorded, Hammers of (30 Joul) was used in this test with specimens of impact see table (2). The test was carried out in accordance with ISO-179. The impact strength value was calculated by dividing the energy in KJ recorded on tester by cross sectional area of specimen.

The impact strength can be calculated from the following equation:

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

Flexural (bending) test was used in this work. The dimensions and thickness of specimen were measured and recorded. The test was carried out in accordance with ASTM D-790. The flexural modulus was calculated from this test.

The flexural modulus and shear stress were calculated from the following relationships:

$F.S. = 3PS/ 2bt^2$ --------- (2) (MPa)

Where: F.S: Flexural strength P: applied force till the failure of specimen occurs

S: Span, b: width of specimen, t: thickness of specimen

3. Results and discussion

The mechanical properties of natural fibers vary considerably depending on the chemical and structural composition, fiber type and growth conditions. The mechanical properties of composites are influenced mainly by the adhesion between the matrix and fibers.

The results of impact strength for a sample of a composite reinforced with chopped carbon fibers are smaller than the results of composite reinforced with natural fibers and the results with hybrid composite reinforced with (natural fibers (SF)/carbon fibers /Epoxy), this can be seen in the table {2}. The carbon fiber reinforced composites which are susceptible to impact damage because of the brittle characteristics of the reinforced fibers; show low impact energy absorption [9].

The existence the natural fibers in hybrid composite increase the impact strength of samples, see figure (1). This can be explained due to the presence of chemical treatment and modification which provided a stronger adhesion between fibers and matrix these results agree well with **Ismail** and **Zamani** , they found the presence of chemical treatment and modification which provided a stronger adhesion between fibers and matrix.[1]

Shorter pull-out is observed in hybrid composites which indicated stronger adhesion between natural fibers and (matrix, carbon fibers) resulted higher impact strength than carbon composite. These results agree well with Sharifah .et al., where found little fiber pull out which indicate to good bond and interfacial adhesion between the matrix and fiber so higher interfacial stress can develop,

reducing the work of fracture and causing the fracture to be more brittle [10].

Cane sugar composites have higher results of impact strength than other chopped carbon composites that means an increase in fracture energy was accompanied by increasing fiber toughness[6].Moreover, this is because the compatibility between cane sugar fibers and epoxy matrix is strong enough to support this stress therefore increases the interfacial resistance between these materials, While lack of interfacial bonding between carbon fibers and epoxy matrix because carbon fibers are also generally chemically inert; that is, interfacial interactions in carbon-fiber-based composites would be rather weak [11].

The results of natural fibers composites have higher value of flexural strength than chopped carbon fibers composites due to compatibility between matrix and natural fibers. The presence of the compatibilizer between cane sugar fibers and epoxy resin had a very significant effect on increasing the composites flexural strengths, see figure(2) .This was attributed to the improvement of the interface between the two phases due to the better compatibility of the phases [12].

Moreover; the continuous cane sugar fibers give the highest flexural strength but with high directionality of properties .while randomly oriented short fibers do not lead to this indirectionality of properties and do not give such high strength [4].

The flexural strengths of hybrid composite increase with the natural fiber present and strengths of up to 129.45 MPa were achieved with the fiber loading of 20% by volume fraction.

4. Conclusions

The mechanical properties of composites are influenced mainly by the adhesion between matrix and fibers.

The chemical treatments of the fibers improve the mechanical properties of fibers

The cane sugar composite has the higher values of impact and flexural strength than chopped carbon fibers composite; moreover the longer fiber improve flexural and impact strengths.

Chemical modification of carbon fiber surface is needed to increase attractive interactions at the fiber/polymer interface.

This shows that the combination of fibers capable to overcome the weakness of individual chopped carbon fiber where there is lack of interfacial bonding between chopped carbon fiber and polymeric matrix.

6. References

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Table (1) Volume fraction of Cane sugar and carbon fibers of composite

Sample No.	Composite type	V_f of cane sugar fiber(SF)	V_f of carbon fiber(CF)
1	Cane sugar fiber/Cane sugar fiber /Sugar fiber	30%	0%
2	Carbon fiber/Cane sugar fiber/Carbon fiber	20%	10%
3	Carbon fiber/Cane sugar fiber/Carbon fiber	10%	20%
4	Carbon fiber/Carbon fiber/ Carbon fiber	0%	30%

Table (2) shows some results of mechanical test

Samples No.	Composite Type	Impact Strength(KJ/m^2)	Flexural Strength(MPa)
1	Cane sugar fiber (30%), Carbon fiber (0%)	93.92	490.77
2	Cane sugar fiber (20%), Carbon fiber (10%)	72.55	129.45
3	Cane sugar fiber (10%), Carbon fiber (20%)	51.82	94.19
4	Cane sugar fiber (0%), Carbon fiber (30%)	23.09	93.19

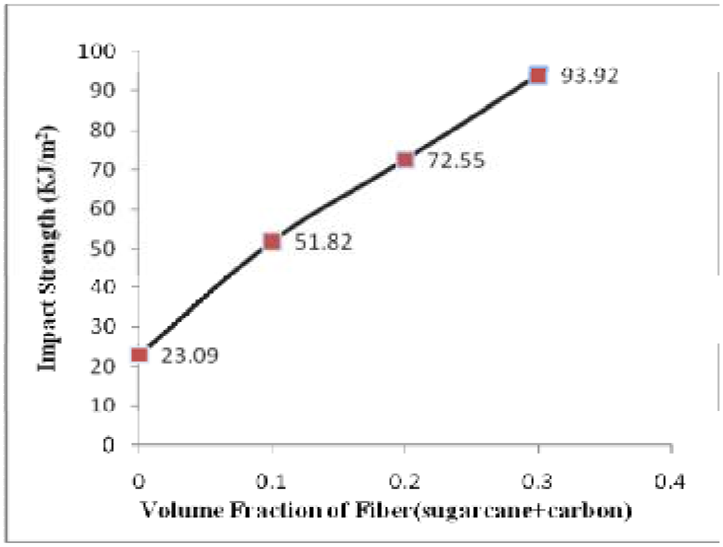

Figure (1) Effect of Impact strength on varying the relative volume fraction in sugarcane and carbon in sugarcane/carbon /Epoxy

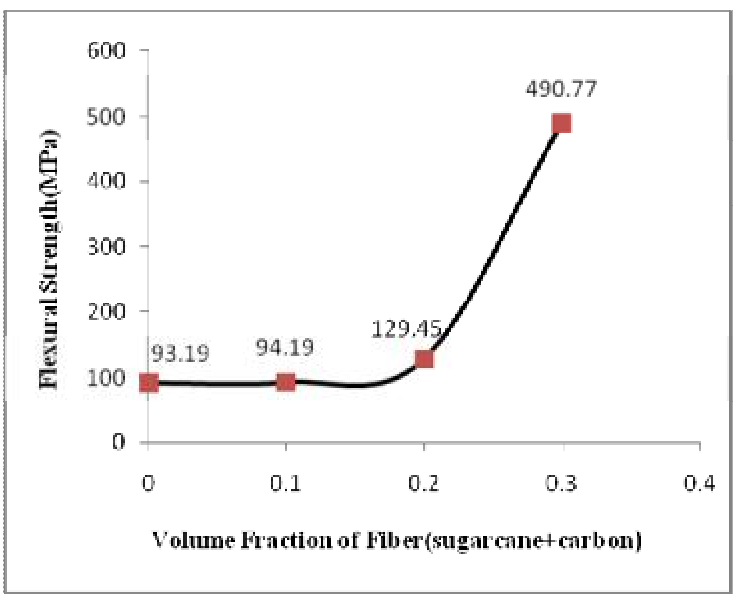

Figure (2) Effect of flexural strength on varying the relative volume fraction in sugarcane and carbon in sugarcane /carbon /Epoxy