Study on the Flexural and Impact Properties of Short Okra Natural Fiber Reinforced Epoxy Matrix Composites

Aseel Mahmood Abdullah
Materials Engineering Department, University of Technology/Baghdad
Email: aseelmahmood20@yahoo.com
Ahmed Mudhafar Hashim
Engineering Collage, University of Al-Qadissiya/ Al- Qadissiya
Email: ahmedmudhafar@ymail.com

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ABSTRACT

The okra natural fiber reinforced epoxy matrix composites were prepared by hand-lay-up. The weight fractions of okra fiber are (1, 3, 6, 9, and 12% by weight wt). The flexural properties and impact resistance of composites were determined by the flexural and impact tests. The maximum modulus of elasticity is (844.93 MPa) at the weight fraction of (12 % wt) of okra fiber, comparison with (91.25 MPa) for virgin epoxy material. The maximum impact energy is (0.75 J) at the weight fraction of I(12 % wt) of okra fiber, comparison with (0.05 J) for virgin epoxy material.

Keywords: okra natural fibers, epoxy, flexural properties, and impact properties.

دراسة خواص الانحناء والصدمة للمادة المركبة ذات الأساس من الايبوكسي المقواة بألياف نبات البامية

الخلاصة

في الدراسة الحالية تم تحضير المادة المركبة ذات الأساس من الايبوكسي المقواة بألياف نبات البامية بكسور وزنية مختلفة (1, 3, 6, 9, 12 % wt) بطريقة الصب اليدوي ، ومن ثم دراسة خواص الانحناء والصدمة لنماذج المادة المركبة. وقد بينت النتائج أن أعظم قيم لمعامل الإنحناء كانت (844.93 MPa) وذلك للمادة المركبة المقواة بـ (12 % wt)من ألياف نبات البامية مقارنةً بـ (91.25 MP) للايبوكسي غير المقوى. أما بالنسبة لنتائج اختبار مقاومة الصدمة فقد كانت أعظم قيمة للطاقة الممتصة (0.75 J) وذلك للمادة المركبة المقواة بـ (12 % wt) من ألياف نبات البامية مقارنةً بـ (0.05 J) للايبوكسي غير المقوى.

INTRODUCTION

The study on using natural fibers to reinforce composite materials increased dramatically during the last few years. Fiber-reinforced composites consist of reinforcing fibers and a polymer matrix, which acts as a binder for the fibers [1]. There is a growing interest in the use of natural fibers as reinforcing components for both thermoplastic and thermoset matrices, because of the ideal benefits offered by natural fibers such as convenient renewability, biodegradability, and environmentally friendliness. The natural fibers have the potential to be used as a replacement for glass or other traditional reinforcement materials in composites. These fibers are abundant, cheap and renewable [2]. Currently, automotive and construction industries have been interested in composites

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2412-0758/University of Technology-Iraq, Baghdad, Iraq

reinforced with natural plant fibers as alternative materials for glass fiber reinforced composites in structural applications with modest demands on strength reliability [3]. Natural fibers are classified into wood fibers and non-wood natural fibers as shown in Figure (1).

The chemical composition of natural fibers varies depending upon the type of fibers. The chemical composition as well as the structure of the plant fibers is fairly complicated [5]. Plant fibers are a composite material designed by nature. The fibers are basically a rigid, crystalline cellulose microfibril-reinforced amorphous lignin and/or with hemicellulosic matrix. Most plant fibers, except for cotton, are composed of cellulose, hemicellulose, lignin, waxes, and some water-soluble compounds, where cellulose, hemicelluloses, and lignin are the major constituents [6].

A new natural fiber name okra was introduced in this search. Okra fiber reinforced polymer composites is useful for the preparation of doors for house hold purposes with light weight [7]. M. Shamsul Alam et al. [8] studied chemical analysis of okra fiber and its physico- chemical properties. The chemical composition of okra fiber values are 67.5 % cellulose, 15.4 hemicellulose, 7.1 % lignin, 3.4 % pectic matter, 3.9 % fatty and waxy matter, and 2.7 % aquous extract. Dip Saikia [3] calculated the Water Absorption Behavior of Plant Fibers such as leaf fiber of bowstring hemp, bark fiber of okra and seed fiber of betel nut at Different Temperatures. The water absorptions behaviors of all fibres were studied at temperature range 300-340 K. The increase of diffusion with temperature indicated the activation of the diffusion process at higher temperature. The water uptake was found to increase with increasing temperature for all samples. G M Arifuzzaman Khan et al. [9] investigated the effects of alkali (10 % NaOH solution) and Acrylonitrile monomer surface modification on the mechanical and water absorption properties of okra fiber. N. Srinivasababu et al. [7] studied the effect of chemically treated on the Tensile properties characterization of okra woven fiber reinforced polyester composites. Chemically treated okra woven FRP composites showed the highest tensile strength and modulus of 64.41 MPa and 946.44 MPa respectively. Specific tensile strength and modulus of untreated and treated okra FRP composites is 34.31% and 39.84% higher than pure polyester specimen respectively. In another study, N. Srinivasababu et al. [10] studied The tensile properties of okra fiber reinforced polyester composites were compared with sisal and banana fibers reinforced polyester composites. Chemically treated okra fiber reinforced polyester composites at maximum volume fraction showed tensile strength, modulus, specific tensile strength and modulus of higher than that of the sisal and banana fibers reinforced polyester composites specimens.

OBJECTIVE OF THIS SEARCH

The objective of the search are outlined below:

1- Extraction the okra fiber from the stem of the okra plant.
2- Fabrication of okra fiber reinforced epoxy based composite.
3- Evaluation of mechanical properties (flexural strength, and impact resistance).

4- Besides all the above objectives is to develop a new class of composites by incorporating okra fiber reinforcing phases into a polymeric resin.

EXPERIMENTAL WORK

Materials Used Okra Fiber Extracted

The okra stem was collected from a small farm in Baghdad. New fiber considered in the present research was extracted by the following procedure. The removed okra stems were placed in a pit containing stagnant mud water for 9 days at ambient conditions. On 10^{th} day the stems were washed with sufficient quantity of water till complete pulp was detached from fiber.Then the fiber was dried for 7 days at ambient conditions. **Figure (2)** shows the extracted okra fibers. Final, okra fiber in the form of short fibers (10mm) were used in this work with direction at random.

Matrix Materials

The matrix material used in this work was based on commercially available epoxy. Quick Mast 105 epoxy was based on commercially produce from Quick Mast company. The properties of the liquid resin are the following in **Table (1)**.

Preparation of The Composite Samples

Short okra fiber reinforced epoxy composites were prepared by hand-lay-out method. Molds used in this study were made from steel. Epoxy and hardener were mixed in a container in the ratio of (3:1) and stirred well for 5–7 minutes. Before the mixture was placed inside the mould, the mold has initially been polished with a release agent (Vaseline) to prevent the composites from sticking onto the mold upon removal. Finally, the mixture was poured into the mold and left at room temperature for 24 hours until the mixture was hardened. When the composite was hardened, it was removed from the mold as shown in **Figures (3, and 4)**. The weight fractions of okra fiber were (1, 3, 6, 9, and 12% wt).

MATERIALS' CHARACTERIZATION

Flexural test

The flexural test specimen dimension was 150mm × 12mm× 10mm (length x width x thickness) and three point bend method was used for flexural test according to ASTM D790[11, 12].

The modulus of elasticity in bending, or the flexural modulus (E_{bend}), is calculated in the elastic region of Stress – deflection curve [12, 13]:

$$E_{bend} = \frac{FL^3}{4b\delta d^3} \quad \dots (1)$$

Where, *L* is the span length of the sample. F is the load applied; b, d, δ are the width and thickness of the specimen, and deflection of the beam respectively.

Impact Test

The flexural test specimen dimension was 55mm × 10mm× 10mm (length x width x thickness). Impact tests were performed on an Pendulum impact testing machine model XJU-22. The test method adopted was consistent to ASTM D256-78 [11]. All the test specimens were un-notched. A total of six samples were tested and the mean value of the absorbed energy was taken.

RESULTS AND DISCUSSION

Flexural Test Results

The Figures (5, 6, 7, 8, and 9) shows the load – displacement for epoxy matrix composites reinforced with 1, 3, 6, 9, and 12 % wt okra fiber respectively. While the Figure (10) show the relationship between modulus of elasticity of composites and weight fraction of okra fiber. The increase in weight fraction of okra fiber the increase in modulus of elasticity. The maximum modulus of elasticity is 844.93 MPa for the composite reinforced with 12 % wt of okra fiber. The increase in modulus of elasticity or stiffness of composite due to the increase in fiber content of okra fiber [9] and because of the okra fiber has a higher modulus of elasticity comparison with banana, sisal, and other natural fibers [10].

Impact Test Results

Figure (11) show the relationship between impact energy of composites and weight fraction of okra fiber. The result of impact test showed that the okra fiber improved the impact strength properties of the virgin epoxy material. Higher impact strength value leads to the higher toughness properties of the material [14]. The maximum impact energy is 0.75 J for the composite reinforced with 12 % wt of okra fiber, while the impact energy is 0.05 J for epoxy material. The okra natural fiber composites tested displayed low impact strengths due to the lignin at surface of natural fiber, therefore, the major limitations of using these fibers as reinforcements in such matrices include poor interfacial adhesion between fiber and matrix, and difficulties in mixing due to poor wetting of the fiber with the matrix. This in turn would lead to composites with weak interface [15 - 19]. It is well known that the impact response of fiber composites is highly influenced by the interfacial bond strength, the matrix and fiber properties. Impact energy is dissipated by debonding, fiber and/or matrix fracture. The former is common in composites with strong interfacial bond while the occurrence of the latter is a sign of a weak bond [11].

CONCLUSIONS

1- Okra natural fiber can be extracted from the okra stems through aerobic decomposition in mud water manually. The optimum time period for extraction of fiber was 9 days.

2- The flexural modulus of epoxy matrix composite increased when short okra fiber increased the weight fractions of okra fiber are (1, 3, 6, 9, and 12) % wt.

3- The results of the impact strength test showed that the okra fiber improved the impact strength properties of the virgin epoxy material.

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Table (1)

Compressive strength at 20 ̊C	**Specific gravity**	**Viscosity at 35 ̊C**
72 N/mm^2	1.04	1.0 poise

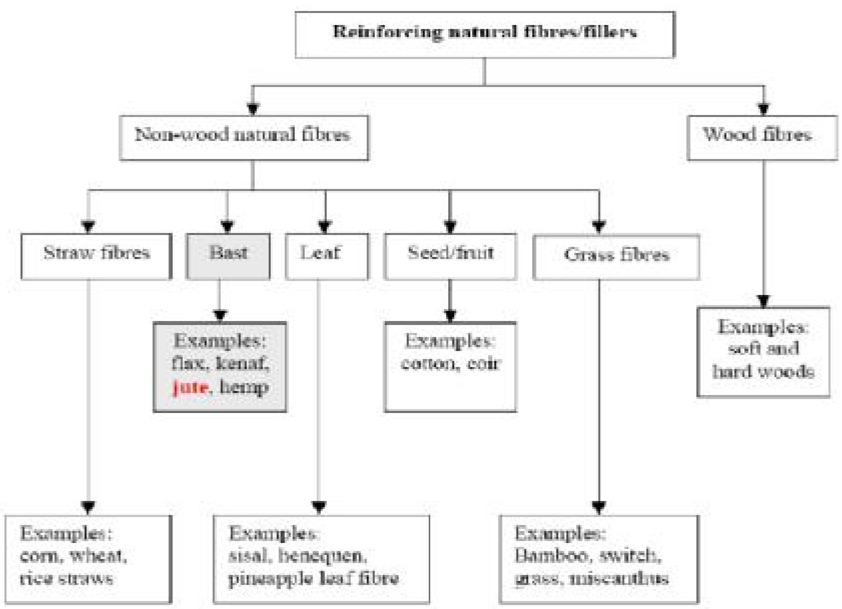

Figure (1) Classification of natural fibers which can be used as reinforcement of polymer [4].

Figure (2)Extracted okra fibers.

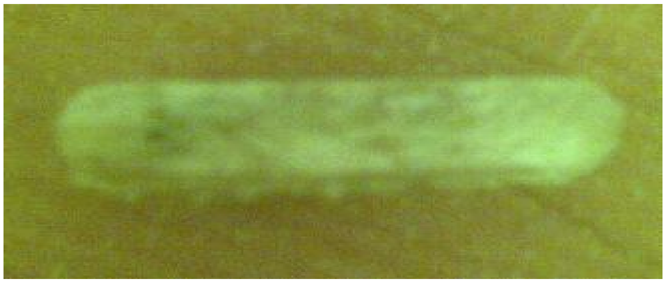

Figure (3)Impact test specimen of okra fabric reinforced epoxy composite.

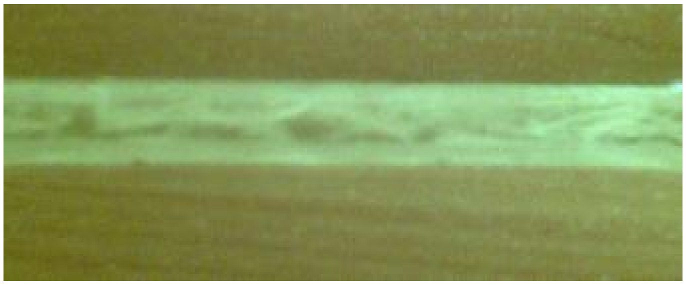

Figure (4)Flexural test specimen of okra fabric reinforced epoxy composite.

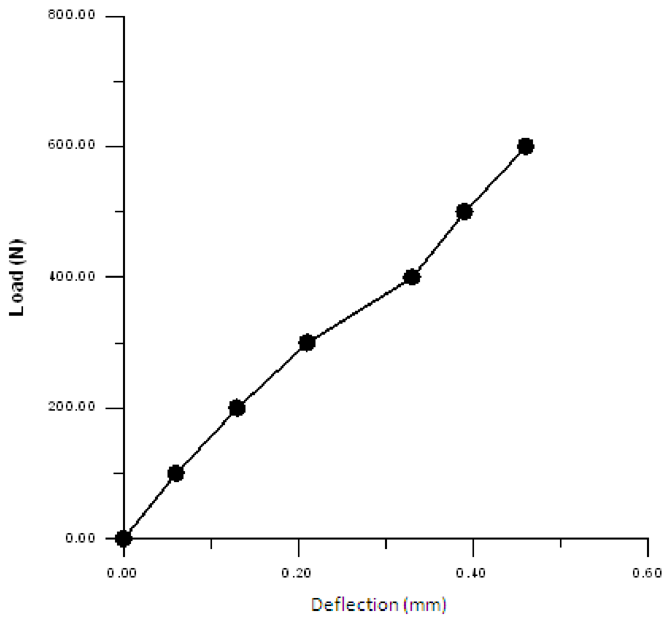

Figure (5)The load – displacement of epoxy matrix composite reinforced with 1 % wt okra fiber.

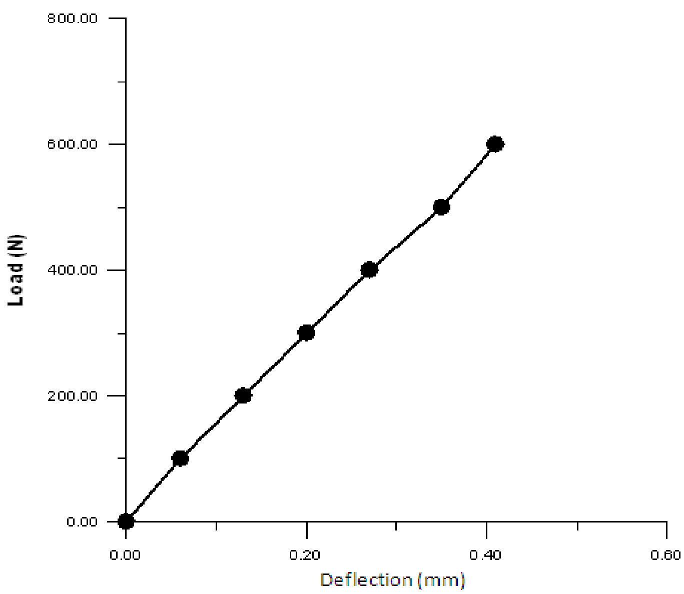

Figure (6)The load – displacement of epoxy matrix composite reinforced with 3 % wt okra fiber.

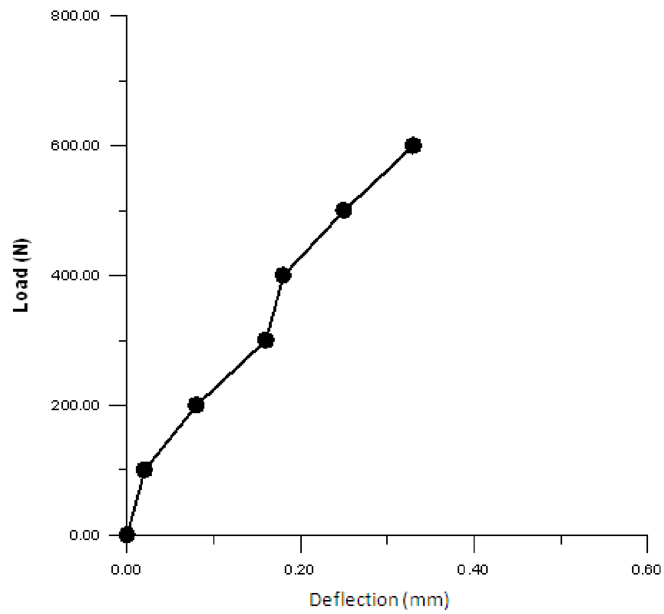

Figure (7)The load – displacement of epoxy matrix composite reinforced with 6 % wt okra fiber.

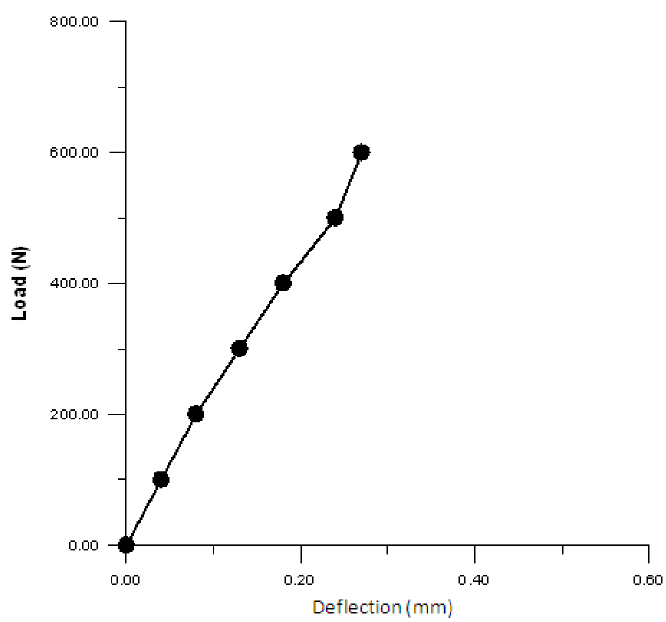

Figure (8)The load – displacement of epoxy matrix composite reinforced with 9 % wt okra fiber.

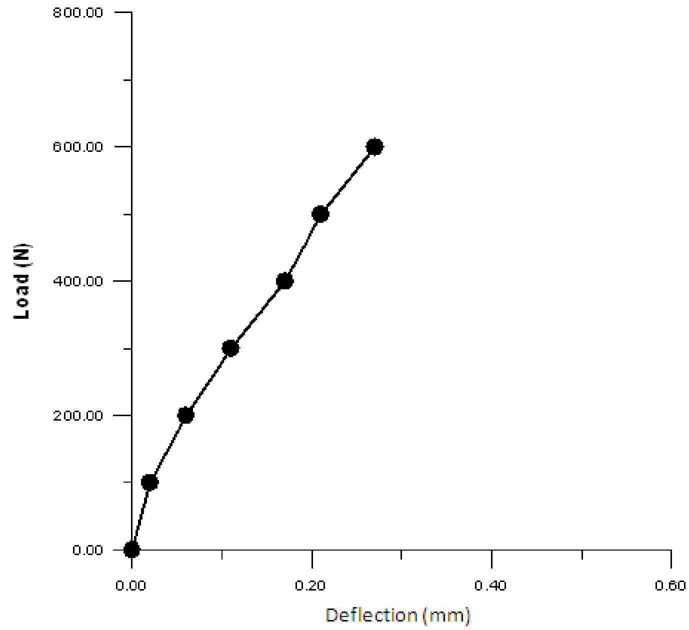

Figure (9)The load – displacement of epoxy matrix composite reinforced with 12 % wt okra fiber.

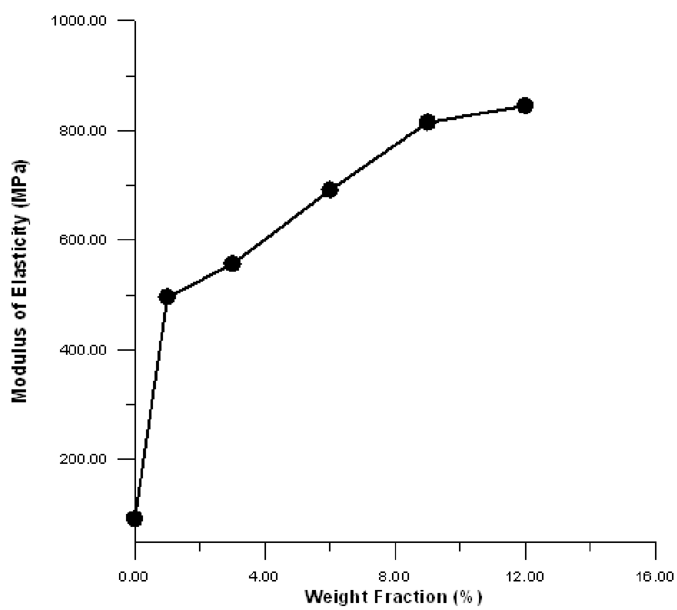

Figure (10) Effect of weight fraction of short okra natural fiber on modulus of elasticity of epoxy matrix composite.

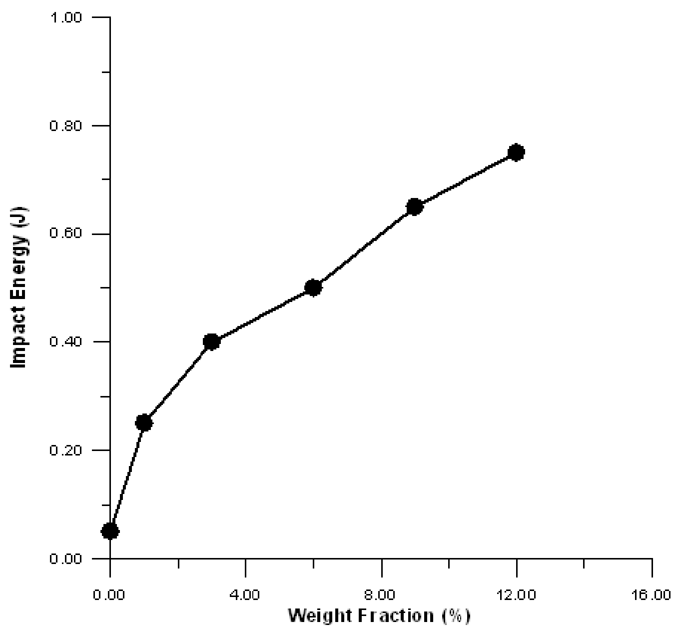

Figure (11)Effect of weight fraction of short okra natural fiber on impact energy of epoxy matrix composite.