Mechanical properties of carrot fiber - epoxy composite

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Abstract:

Interest has largely centered on the use of plant fibers to reinforce plastics, because these fibers are abundant and cheap. Carrot fibers (Curran) have been extracted from carrot, left over from carrot juice manufacture. The fibers of two sizes fine (50<µm) and coarse (100-150 µm) have been mixed with epoxy in four levels of loading (10, 20, 30, 40 wt %) respectively. Impact test, shore d hardness test and three point bending test of epoxy and carrot fiber-epoxy composites samples have been determined. The impact strength values of samples prepared with fine and coarse fibers increased as compared with pure epoxy sample. Hardness values increased, and the Young's modulus values decreased with fiber content of both sizes.

Key words: Natural fibers, polymer composites, mechanical properties.

Introduction:

Over the past two decades plant fibers have been receiving considerable attention as substitute for synthetic fiber reinforcements in polymer. The advantages of plant fibers are low cost, low density, acceptable specific strength, and good thermal insulation properties, reduced tool wear, and reduced dermal and respiratory irritation, renewable resources and recycling possible without affecting the environment [1, 2].

Natural fibers like coir, flax, jute, kenaf, vakka, sisal, bamboo, and banana fibers could potentially be used as a replacement for glass fiber in every application where the ultimate stiffness and strength are not required this includes many current, as well as emerging, applications. Therefore, the applications for this material are vast covering a wide range of manufacturing sectors from automotive to appliances and consumer goods [2-7].

Carrot fiber is nanofiber provides high strength, stiffness, toughness and a very smooth finish. The composite made from carrot fibers has a lower density than carbon fiber. It can also be molded which makes it valuable for many applications. The carrot fibers have stiffness of 130 GPa, strength of up to 5 GPa and density 1.5 g/cm^3 [8, 9].

James et al. [10] found that carrots grown at Perkins, Oklahoma, that harvested at two times during the year once in midsummer and in the late fall contented 25.8-51.2 % fibers**.** Mehmet et al. found carrot seeds cultivated in Turkey contented about 31.99+2.21 % fibers [11]. Blanching et al. found carrot's pulp contained 37-48 % from the total fibers [12].

Carrot fibers composites were used in:

Automotive industry In the early 1930's, Henry Ford examined a variety of natural materials including carrots, cantaloupes, cornstalks, cabbages and onions in a search for potential candidate materials from which he could build an organic car body. He developed a prototype based on Hemp but due to economic limitations at that time the vehicle was not mass

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produced. The steering wheel in a race car is made from carrot fibers paste which injected into the mould to form the part. The steering wheel in a race car is made from composite composed of carrot fibers [9].

Fishing Rods Scottish company Cellucomp, in 2004, has developed a new bio-composite which uses carrot fiber as the main reinforcement material. The first product that was produced using these fibers was a high performance fishing rod. These rods were made by mixing the carrot fibers with carbon fibers it's currently an 80:20 mix. Rods were made using carrot fibers damp twice as rapidly as an equivalent carbon rod, while retaining the same rapid recovery speed as the carbon rod [8].

Sports equipment The carrot fibers material can also be utilized in a range of other sports equipment such as snowboards, road cycling (bike), and boat [13].

In the current study, fibers extracted from carrot have been used as dispersed phase for epoxy matrix. Composites were prepared using hand lay-up technique. The effect of fiber content (10, 20, 30, 40 wt %) on the composites mechanical properties was studded.

Materials and methods:

Materials:

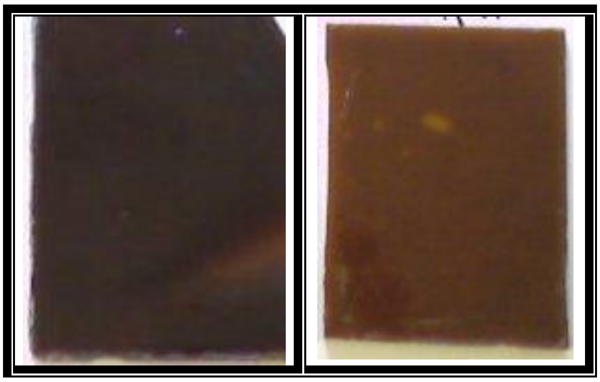
Filler: Carrot seeds were purchased locally from vegetable supplier. They were cleaned to remove all foreign matter such as dust, dirt, and stones. The juice was removed from carrot seeds the solid waste from carrot juice is rich in fiber which regarded as a functional fiber source. The waste was dried to a constant weight and then grounded by using a grinder and sieved. Two sizes were obtained. Once (fine fiber) is less than 50 µm and the other (coarse fiber) is between 100-150 µm which represent as accumulated fibers.

Matrix: epoxy resin group type Quickmast 105 (DCP) was used. Specific gravity and viscosity of the epoxy resin were 1.04 and 1 poise respectively at 35^oC. The ratio between resin and hardener for this study was 3:1 by weight.

Processing of composites:

To prepare the composite samples, a mould of size (200*150*3 mm^3) has been made from glass. Silicon was used for joining frames. Then plastic sheet was placed in the bottom of the mould. The composites have been prepared with hand lay-up technique. The carrot fiber-epoxy composites were prepared with 10, 20, 30, and 40 wt. % fiber content for both sizes.

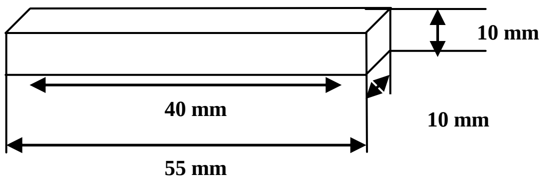
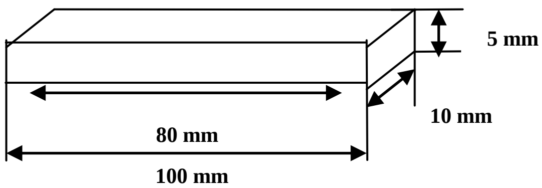
Initially epoxy resin and hardener have been mixed together based on the weight ratio to form a matrix. Then some of the weighted fibers were added to epoxy resin with continuous mixing. This process has been continued until weighted materials were finished. Then the mixture was poured into the mold. Then it was covered by plastic sheet. The curing time was around 24 h at room temperature (23 ^oC). The composite has been taken out of the mould in the form of a plate as shown in Fig. (1) and was cut and machined to produce samples conforming to the ASTM standards for mechanical properties testing according to the dimensions given in Table (1). All these tests have been carried out for pure epoxy, and carrot fiber reinforced epoxy composites of different loading for the both sizes.



A B

Fig. (1): The prepared composite. (A)-10% fine fiber, (B)-10% coarse fiber.

Table (1): The dimensions of samples according to the ASTM standards

Test type	Test Specimen Specification	Standardization Code
Impact		ASTM-D256-87
Bending		ASTM-D790-86

Impact strength test:

Charpy impact instrument (Testing Machines INC. AMITYVILLE, New York) with 5 J of energy pendulum on the specimen has been used in this test. The impact strength was calculated from the following relation [14]:

$$\text{Im}\,pact \cdot strength = \frac{Energy \cdot of \cdot fracture(Joul)}{Cross - Sectional \cdot area(m^2)}$$ …. (1)

Hardness:

Digital durometer for Shore D hardness testing pocketsize model with integrated probe Standards: ASTM D 2240 has been used.

Three-point bending test:

Three-point test system (Phywe) has been used to determine the modulus of elasticity. The following equations were used to determine Young's modulus of the specimens [15].

$$E = \frac{Mgl^3}{48IS}$$ ……. (2)

$$I = \frac{db^3}{12}$$ …… (3)

Where E is Young's modulus (N/m^2), M is the mass, g is gravitational acceleration ($9.8\frac{m}{Sec^2}$), l is the length of the specimen, I is the moment of inertia, S is the deflection and ($\frac{M}{S}$) is the slope of linear part of the mass-deflection relation, where d and b are the width and thickness of the specimen respectively.

Results and Discussion:

Impact strength:

The Charpy impact test is known as a standardized high strain-rate test, which determines the amount of energy absorbed by a material during fracture. The impact strength has been calculated by using the relation (1). The results are given in Fig. (2) each value obtained represented the average of five samples.

The results show that the coarse size fiber/epoxy composites have higher impact strength value than fine size fiber composites except at 40 wt% fiber content. The total energy absorbed during fracture by the composite samples is quite high when compared to the pure epoxy samples.

As known the impact test is a measure of a given material's toughness. The obtained results may be related to good distribution of carrot fibers within the matrix and interfacial bonding between them leads to significant increase in the energy absorbing capacity of the composite. While in case of using coarse fibers with high loading the resin cannot reach each of the carrot fiber surfaces because of the smaller amount of matrix which result ununiform fibers distribution. When the stress is applied, the matrix cannot transfer the stress effectively. This can influence the impact strength values [3].

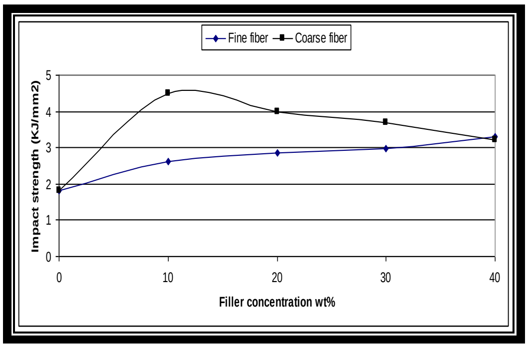


Fig. (2): Impact strength of samples prepared with fine and coarse carrot fibers.

Hardness:

The variation of shore D hardness of samples prepared with fine and coarse sizes fibers was shown in Fig. (3) each datum in the figure is the mean of three measurements.

As observed from Fig. (3) that the hardness of samples increases with increasing carrot fiber content.

The coarse size fiber-epoxy composites have higher hardness than fine size fiber-epoxy composites at 10 and 20 wt% of fiber content. This behavior may be retained to the uniform distribution of coarse fibers which taken high size of the composite surfaces so the applied stress is spread through distributed fibers so high hardness is obtained. While at 30 and 40 wt% of fiber content the hardness of coarse fiber composites is lower than fine fiber composites, this result may be indicated to the ununiform distribution fibers as mentioned before [16].

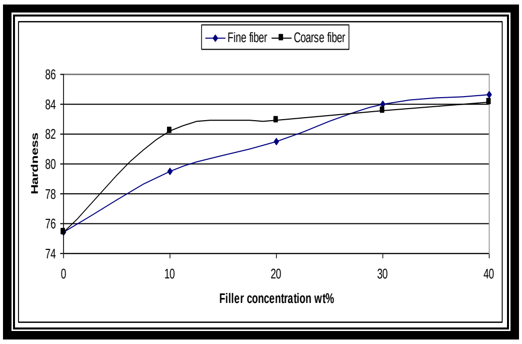


Fig.(3): Shore D hardness of samples prepared with fine and coarse carrot fibers.

Bending test:

Figs. 4 and 5 show the deflection according to the applied load for the samples prepared with fine and coarse carrot fibers respectively. Table 2 and 3 show the average values of the Young's modulus of samples.

In Tables 2 and 3 a decreased trend has been seen in Young's modulus with increased fibers content. This attributed to increase of ductility with increases fibers content. There are no significantly differences in Young's modulus value for same weight content of both sizes.

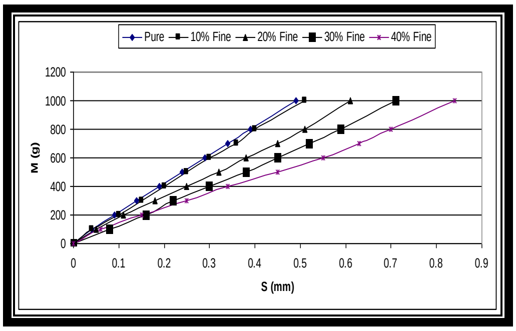


Fig. (4): The deflection versus applied load of samples prepared with fine fiber.

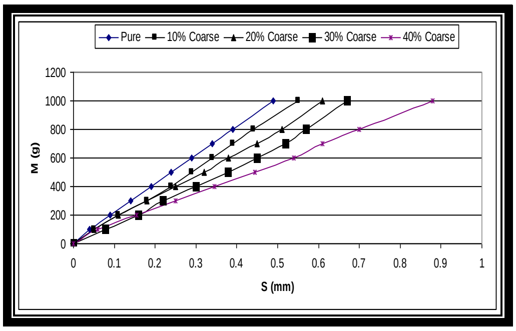


Fig. (5): The deflection versus applied load of samples prepared with coarse fiber.

Table (2): Young's modulus values of pure and composite samples prepared with fine carrot fiber.

Sample	Pure	10 wt%	20 wt%	30 wt%	40 wt%
Young's modulus (GPa)	2.875	2.825	2.653	2.467	2.258

Table (3): Young's modulus values of pure and composite samples prepared with coarse carrot fiber.

Sample	Pure	10 wt%	20 wt%	30 wt%	40 wt%
Bending Strength (GPa)	2.875	2.734	2.678	2.590	2.146

Conclusions:

The process of extraction of carrot fibers is simple. The lower density of carrot fibers is an interesting parameter in designing lightweight material made from carrot fiber-epoxy composite.

The results have suggested that carrot fiber-epoxy composites were more suitable where more energy absorption and ability of deformation was required.

It is concluded that the fiber size effect on the behavior of impact strength with increasing fiber content. High impact characteristics were observed in coarse size fiber composites.

It is also concluded that the shore d hardness value and the ductility of composite samples increased and Young's modulus value decreased with increasing fiber content.

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الخصائص الميكانيكية لمتراكبات الياف الجزر –ايبوكسي

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الخلاصة:

هنالك اهتمام كبير باستخدام الياف النباتات لتقوية البلاستك، لان هذه الالياف متوفرة ورخيصة. تم استخراج الياف الجزر من الجزر المتبقي من عملية عصره. خلطت الالياف بحجمين (µm>50) و(µm 150-100) مع الايبوكسي باربعة نسب (10 ، 20، 30، 40 نسبة وزنية %) على التوالي. تم قياس اختبار الصدمة واختبار الصلادة واختبار الانحناء الثلاثي النقط لنماذج الايبوكسي ومتراكبات الياف الجزر-ايبوكسي. زادت قيم مقاومة الصدمة للنماذج المحضرة بالالياف الناعمة والخشنة مقارنة مع نمودج الايبوكسي لوحده. هنالك زيادة في قيم الصلادة ونقصان في قيم معامل يونك مع زيادة نسبة الالياف لكلا الحجمين.