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Mechanical and Thermal Properties of Date Palm Fiber and Coconut Shell Particulate Filler Reinforced Epoxy Composite

KEYWORDS: Composites, Filler, Fiber, Epoxy, Mechanical & Thermal Properties

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ABSTRACT *In this study a natural fiber extracted from the date palm tree and coconut shell particle filler were used as reinforcement for epoxy matrix composites. Epoxy composite specimens reinforced with date palm fibers, coconut shell particle filler, and date palm fibers/coconut shell particle filler hybrid respectively were fabricated by hand lay-up technique. The filler content in the composite is kept constant to 20 wt %. The variation in the mechanical properties (Three-point bending, Hardness, and Impact strength) and thermal conductivity changes are studied. Results show that these fillers may yield reasonable properties and could be used for low-cost applications.*

Introduction
There is a growing interest in the use of natural plant fibers as reinforcing components for both thermoplastic and thermosetting matrices, because of the ideal benefits offered by natural fibers such as convenient renewability, biodegradability, and environmentally friendliness [1-4]. Recent reports indicate that plant-based natural fibers can very well be used as reinforcement in polymer composites, replacing to some extent more expensive and non-renewable synthetic fibers such as glass [2].

The development of natural fiber reinforced composites become an attractive research lines due to the non-recyclability, high density and health hazards of composites reinforced with synthetic fibers such as glass, carbon and armed fibers . Besides, the greatest problem of using such materials is how to conveniently dispose of them once they have come to the end of their useful life span [3, 4]. Therefore, there has been growing interest in the use of natural cellulosic fibers as the reinforcement for polymeric matrix. Cellulosic fibers are obtained from different parts of plants [5, 6]. Several natural fibers such as sisal [7], jute [8], flax [9], pineapple [10], banana [11], kenaf [12], and coir coconut [13], date palm [14, 15] fibers have been used as a reinforcement and filler in making green polymer composite. The advantage of plant fibers are low cost, low density, acceptable specific strength, stiffness and have no skin irritations effects, and good thermal properties [16, 17].

The 1990s witnessed a burgeoning interest in the development of industrial and consumer products that combine lingo cellulosic fibers and polymer. Early research studies on natural plant fiber reinforced composites have been focused on thermosetting matrix composites and find applications as electrical insulators, semi–structural applications and wear parts [18, 19]. Generally these fibers are not available in a natural fabric form. Some of the above fibers can be woven in biaxial directions [3]. In recent years; the natural fiber woven fabrics and hybrids are attractive as reinforcements since they provide excellent integrity and conformability for advanced structural applications [20, 21].

In this research both of date palm fiber as fabric form extracted from the stem of date palm tree and coconut shell particle filler were used as reinforced materials in epoxy matrix. The present work thus aims to explore the potential of date palm fabric fiber, and coconut shell particle filler as a reinforcing material in polymer composites and to investigate their effect on the mechanical and thermal behaviors of the resulting composites.

Experimental
Materials:
Fillers: date palm fiber as fabric form was extracted from the stem of date palm tree. This was cleaned and washed with water to remove all foreign matter such as dust, and dirt. The fiber fabric was dried in an oven at 100°C to remove residual moisture and then a constant weight obtained.

Coconut shells were procured from a local market. All coir fibers were removed from the shell and then it destroyed to small pieces. These pieces were dried in an oven at 100°C to a constant weight, and ground into fine powder using a grinding machine. The ground coconut shell was therefore sieved with a mesh of sieve of size 50μm.

Matrix: epoxy resin group type (Leyco-pox 103) of low viscosity was used. The ratio between resin and hardener for this study was 3:1 by weight.

Preparation of The Composites
The fabrication of the various composite materials is carried out through the Hand lay-up technique. The filler contents were set at 20 % weight of the matrix. Three different types of epoxy composites were fabricated with three different filler loadings epoxy resin. The designations of these composites are as following:

Epoxy (80 wt %) +Coconut shell filler (20 wt %)

Epoxy (80 wt %) +Date palm fabric fiber (20 wt %)

Epoxy (80 wt %) +Date palm fabric fiber and coconut shell filler (hybrid) (20 wt %).

To prepare the composite samples, a mould of size (200×150×3 mm3) was made from glass. Silicon was used for joining frames. Then a plastic sheet was placed in the bottom of the mould. Initially epoxy resin and hardener were mixed together based on the weight ratio to form a matrix. For the preparation of epoxy/coconut filler composite some of the weighted fillers were added to epoxy resin with continuous mixing to disperse the fillers in the matrix. This process was continued until weighted materials were finished.

Volume : 3 | Issue : 4 | April 2013 | ISSN - 2249-555X

Then the mixture was poured into the mould. Then it was covered by plastic sheet. While the epoxy/date palm fabric fiber composite preparation was concluded by adding fabric in the mould, before pouring of resin. With the help of roller composites was pressed so that proper spreading of resin will take place and also voids will be minimized. And finally the epoxy/ hybrid fillers composite preparation is combined of both processing methods as mentioned above. The cast of each composite is cured under a load for 24 hrs at room temperature (26°C-29°) before it removed from the mould. After curing composites were taken out of the mould in the form of a plate as shown in Fig. (1), that was followed by a post-cure at 60 °C for 4hrs.The specimens were cut and machined to produce samples conforming to the ASTM standards D256-87 and D790-86 for (impact and bending) testing respectively and hardness testing, as well as for thermal conductivity)Lee's disk) testing. All these tests were carried out for pure epoxy, and reinforced epoxy composites of different loading fillers.

Figure (1): The Prepared Composite.

Three-Point Bending Test

Three-point bending test system (Phywe) is used to determine the modulus of elasticity. The distance between the supports was fixed at 80mm. The following equations are used to determine Young's modulus of the specimens [22].

$$E = \frac{Mgl^3}{48IS} \quad \ldots\ldots\ldots\ldots (1)$$

$$I = \frac{db^3}{12} \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where E is Young's modulus (N/m^2), M is the mass, g is gravitational acceleration (9.8m/s^2), l is the length of the specimen, I is the moment of inertia, S is the deflection and (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.

Hardness

Hardness is a measure of materials resistance to localized plastic deformation. Digital durometer for Shore D hardness testing pocketsize model with integrated probe Standards: ASTM ISO 9001 was used.

Impact Strength Test

This test determines the amount of energy absorbed by a material during fracture, which refers to the materials toughness. The impact strength test for specimens of dimension 55×10×10mm^3 was obtained by using Charpy impact instrument (Testing Machines INC. AMITYVILLE, New York) with 5 Joule of energy pendulum on the specimen is used in this test. The impact strength is calculated from the following relation [23]:

$$\text{Impact Strength} = \frac{\text{Energy of fracture (Joul)}}{\text{Cross sectional area } (m^2)} \ldots (3)$$

Thermal Conductivity Test

Lee's disc instrument is used to calculate thermal conductivity of the samples under test. The heat (e) (W/ m^2.K) that flows through across sectional area of the sample per unit time is calculated from the following equation [24]:

$$IV = \pi r^2 e\left(T_A + T_B\right) + 2\pi re\left[d_A T_A + d_S \frac{1}{2}\left(T_A + T_B\right) + d_B T_B + d_C T_C\right] \quad \ldots\ldots\ldots (4)$$

Where, I is the current value through the electrical circuit, V is the supplied voltage, and r is the radius of disc.

T_A, T_B and T_C are the temperature of the brass discs A, B and C respectively. d_A, d_B and d_C are the thickness of the brass discs A, B and C respectively. d_S is the thickness of the sample.

The values of thermal conductivity K (W/m. K) are calculated by applying the equation:

$$K\left(\frac{T_B - T_A}{d_S}\right) = e\left[T_A + \frac{2}{r}\left(d_A + \frac{1}{4} d_s\right)T_A + \frac{1}{2r} d_S T_B\right] \quad \ldots\ldots (5)$$

Results and Discussion

Three–Point Bending (flexural) Test

In this work, three point bending tests were performed in the elastic range on samples. The test results for flexural property of virgin epoxy and reinforced epoxy composites presented in Fig. (2), which shows the effect of load on deflection of the samples. On the whole, all of the reinforced samples showed a degree of stiffening according to the strain decreases with the filler content at the same holding.

The values of Young's modulus derived from the tangential slope of the load- displacement curve are calculated, and shown in Fig.(3) or given in Table(1). The flexural modulus which is used as an indication of materials stiffness in static bending condition shows an increase in Young's modulus with the presence of filler. The flexural modulus is dependent on a materials tensile and compressive strength, since the test sample is under compression on one side and under tension on the other. There are many_factors affecting the modulus of the composite. The factors are the properties of the materials, modulus and the bonding force between the matrix and fillers.

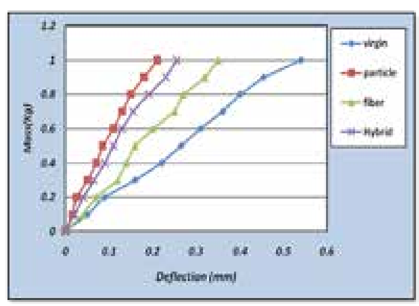
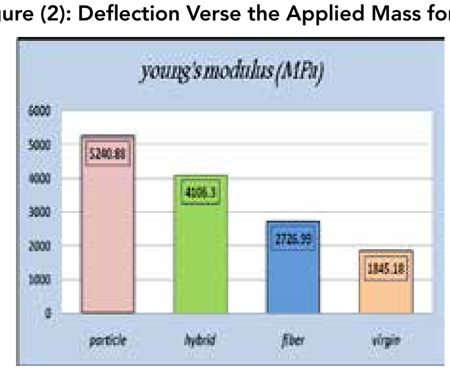


Figure (2): Deflection Verse the Applied Mass for Samples



Volume : 3 | Issue : 4 | April 2013 | ISSN - 2249-555X

Figure (3): Young's Modulus Values for Samples.

Table (1): Young's Modulus Results for Virgin and Composites.

Samples	Young's modulus (Mpa)
virgin	1845.18
Fiber	2726.99
particle	5240.88
hybrid	4106.3

According to the results obtained, the epoxy/date palm fabric fiber composite had higher Young's modulus value compared to the virgin epoxy. This increase is due to the fiber–matrix bonding, so the fibers are strained and carried the load, while the flexural modulus value was significantly higher for the epoxy/coconut filler composite. This can be retained to the coconut filler properties, filler dispersion, and filler-matrix interaction. Since it is believed that the strength behavior of the coconut filler, good dispersion of filler within the matrix and wettability producing isotropic composite properties and the relationship between the interfacial bonding of fillers and matrix in which the fillers strengthen the composite material, so results high flexural modulus(5240.88Pa). The hybrid composite denotes also of high flexural modulus but is little less than the former composite. Here both coconut filler particles and date palm fiber were shared for loading the stress, where reflected their properties, and depends upon the interaction between constituents of the composite. In general the probability of some bubbles and voids were formed which influenced to the result.

Hardness

The measured hardness values of virgin epoxy and all the three composites are presented in Fig. (4). It is obvious that the hardness of composites is higher than virgin epoxy. This must be expected because as filler get into the matrix the loading stress is shared by fillers resulting more rigid. Also the modulus results obtained are an indicator to improvement in hardness. It should be mentioned that surface hardness depends also on the intrinsic properties of fillers, bonding at the matrix and filler interface, and the distribution of fillers within the matrix. The hardness of epoxy/date palm fiber composite is attributed to interfacial adhesion in the composite which restricts the motion of the polymer chains in the vicinity of the fiber surface and leads to an increase in hardness. Furthermore, it can be noticed that the hardness of hybrid composite is greater than former as the effect of coconut filler content.

The hardness of epoxy /coconut filler composite is superior to those of date palm fiber and hybrid fillers reinforced composites. This result may be retain to hard and stiff behavior of coconut particles, and the high interaction of coconut hard particles with the matrix which restrain movement of the matrix in the vicinity of each particle ,thus enhanced material hardness.

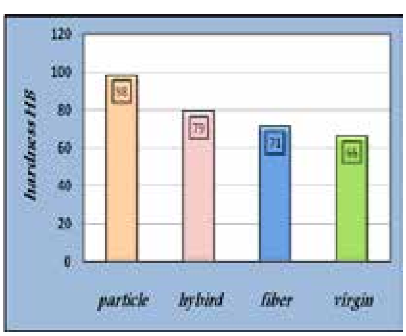


Figure (4): Vickers Hardness for virgin epoxy and composites

Impact Behavior

The effect of impact strength of virgin epoxy and composites for un notched samples is shown in Fig. (5), the impact strength of all composites increases as compared to virgin epoxy. For pure (virgin) epoxy a crack growth rate is locally accelerated as a result of the brittle behavior of resin. The results indicate that composites are tougher than epoxy matrix. In the epoxy/date palm fiber composite, the crack is deflected and pinned by the reinforcing obstacles so that its velocity tends to slow down. In fact, several mechanisms act together and contribution to the fiber composite toughness, which are crack deflection, debonding between fibers and matrix, pull out of fibers from the matrix so dissipate energy by friction, and fiber bridging mechanisms [25, 26].

The results show that epoxy /coconut filler composite have higher impact strength value than virgin epoxy. 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 coconut filler within the matrix and interfacial bonding between them leads to significant increase in the energy absorbing capacity of the composite, and this be come more with hybrid composite.

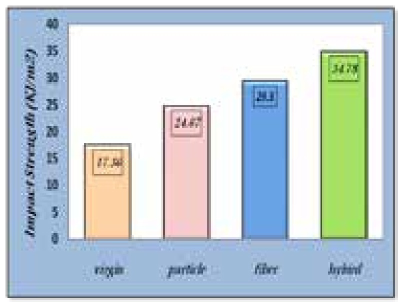


Figure (5): Impact Strength for Virgin Epoxy and Composites

Thermal Conductivity Test

Conductivity is one such important thermal property that needs to be evaluated for any new composite system. Generally, measuring the thermal conductivity accurately is helpful to study the heat transfer process and mechanisms in composite materials. Thermal conductivity has been measured for samples by using Lee´s disk and calculated with the application of equation (5).The results are shown in Fig. (5),which revealed an increases in thermal conductivity of composites as compared with virgin epoxy. Heat flows within a material by the transmission of phonons (thermal carrier) and free electrons (if present). Both of these carriers have a certain mean free path between collisions and an average velocity. The phonon velocity is high in light, stiff materials. The mean free path of a phonon is structure sensitive and can be large in pure specimens of high perfection and large grain size .Polymers have no electrons and low stiffness (low phonon velocity), so that conductivities are low.

The increasing in thermal conductivity of composites was caused by the presence of fillers. The conductivity of a composite is affected by the interface adhesion between fillers and matrices, since the conductivity may be impaired by the presence of an interfacial layer of some sort, or by voids or cracks in the vicinity of the interface. Moreover the moisture content of natural fillers. According to the results obtained these composites can be classified as low thermal conductivity behavior. However there was some variation in conductivity of composites, since the hybrid composite created higher thermal conductive. This may be retained to the interaction between components, provided high toughness of material, so as a result conducting area will increase. The conductivity of date palm fiber reinforced epoxy composite is lower than

Volume : 3 | Issue : 4 | April 2013 | ISSN - 2249-555X

particulate composite .This may be retained to the present of some voids in the vicinity of interface which cause of carrier bent or scattered and also may be of moisture retained. The coconut particles provided stiffness composite, so an increase of phonon velocity and then of thermal conductivity.

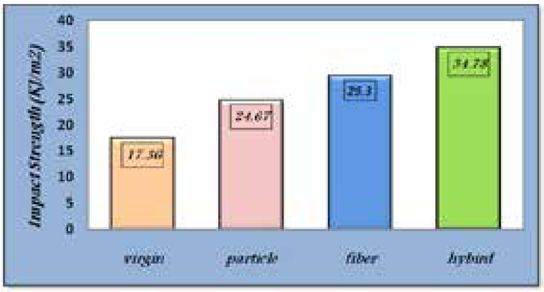


Figure (5): Thermal Conductivity Values for Samples.

Conclusion

This experimental investigation of mechanical and thermal behaviors of date palm fabric fiber and coconut shell particle filler reinforced epoxy composites leads to the following

conclusions:

1- This study shows that preparation of date palm fabric fiber and coconut shell particle filler hybrid reinforced epoxy composite is possible by hand lay-up technique.
2- Mechanical characterization of the composites reveals that hybrid fillers had significant effect as compared with each composite that denoted in this study.
3- Natural fillers such as date palm fabric fiber and coconut shell particle filler can be used effectively as reinforcing materials for epoxy composites. It can be said that composites prepared from these fillers can replace synthetic fillers in some applications where high strength and stiffness is not the major concern.
4- The thermal conductivity results of composites indicates

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