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Effect of the Addition Coconut Shell Powder on Properties of Polyurethane Matrix Composite

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Abstract

This work focuses on the preparation of base polyurethane matrix composite materials by (Hand Lay-Up) method, and studying the effect of selected weight fractions (2, 4, 6, 8, and 10) % wt of (coconut shell powder) particles on some properties of the prepared composite. Some mechanical tests were used to evaluate the prepared system (Tensile, Compression, Impact, and Hardness) tests, and a physical test of (Water absorption %), and all tests were accomplished at room temperature. Maximum results of tensile strength, compression strength, impact energy, hardness and water absorption were (31.3 MPa), (53 MPa), (0.156 J), (82 Shor (D)), (0.345 %) at using (6% wt, 6% wt , 2% wt , 10% wt ,10% wt) respectively. Improved properties of the samples reinforcing for the sample as pure, tensile strength increased to double almost and compressive strength by 12% and impact energy up to 4% and hardness by 17% and the percentage of water absorption into doubled.

Keywords: Polyurethane - matrix composite, Mechanical properties and Water Absorption of composites.

1. Introduction

Composite materials formed by natural materials and polymeric matrices constitute a current area of interest in composites research. The use of natural materials has drawn much attention in the two last decades due to the economic and ecological advantages of the obtained composites [1]. The properties of many materials such as flax, hemp, jute, ringdove, were studied with thermosetting matrix [1, 2]. The ratio price/performance, the lightness and the biodegradability are the assets to valorize natural materials in different industrial sectors [3]. A great development in this field has been noticed, mainly driven by the automotive industries [3 and 4]. Polyurethane resins are attractive due to their structural versatility (as elastomer, thermoplastic, thermosetting, rigid and flexible foams), as well as the fact that they can be derived from either petroleum or vegetable oils [5]. Composite materials are multi phase materials obtained through the artificial combination of different materials in order to attain properties that the individual components by themselves cannot attain. They are multiphase materials in which the different phases are formed naturally by reactions, phase transformations [3 and 4]. Composite materials can be designed to satisfy the needs of technologies relating to the aerospace, automobile, electronics, and construction, and energy, biomedical and other industries. As a result, composite materials constitute most commercial engineering materials [4].

The following is a review of different uses of the polyurethane in polymer matrix composites. The Researcher (Zhou, et.al. in 2005) had studied the polyurethane matrix composites reinforced with aluminum oxide (Al_2O_3) particles ,where see the Improvement in the wear resistance of polyurethane ,and Both the tensile strength and elongation at rupture of the composites were found to decrease with the content of Al_2O_3 particles and the hardness increased gradually. [6]. researcher (Malachy, et.al, 2006) had studied the mechanical properties (tensile strength, compression strength and impact energy) of groundnut husk powder filled polyurethane composite. It was observed that the tensile strength increased marginally an increase in filler content, while the impact strength decreased with increased filler loading [7]. And Researcher (Puneet kumar, 2009) had studied the addition of $CaCO_3$ to reduced friction and therefore reduced the effects of abrasion. The results of this experiment show that the addition of the $CaCO_3$ nanofiller is beneficial to the wear resistance as well as healing ability of PU [8]. And Researcher (**Hong. et.al, 2009)** had studied the polyurethane-based coatings reinforced by ZnO nanoparticles (about 27 nm). It found that significant improvement in Young's modulus and tensile strength, and the abrasion resistance. Moreover, the antibacterial property test showed an excellent antibacterial activity [9].

2. Experimental Work

2.1. Mould Preparation

All the required moulds for preparing the test specimens were made from glass with dimensions of (300×300×5) mm. The mould was coated with transparency film on the base while the internal walls were covered with fablon to avoid sticking between cast material and the mould.

Figure (1): the shape of the prepared mould.

2.2. Test Specimens Preparation

This work focuses on the preparation of base polyurethane matrix composite materials by (Hand Lay-Up) method, the test specimens' preparation are explained as follows:

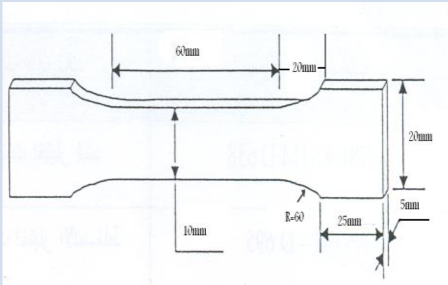
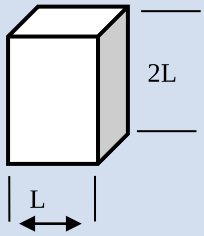
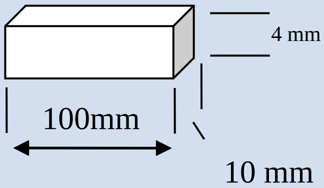
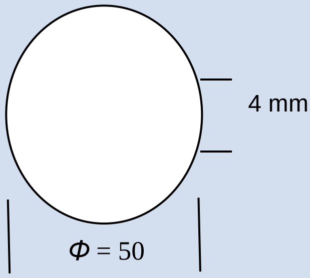
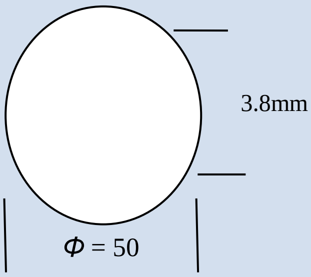
The reinforcement material of (**coconut shell powder**). was calculated according to the required weight fractions , and The mass of the resin (polyurethane) was calculated, according to the required volume of cast, the hardener, and added as a weight % with an amount of (3:1).

The reinforcement filler of (**coconut shell powder**) and the matrix were mixed by (Hand Lay-Up) method at room temperature continuously and slowly to avoid bubbling during mixing, and then the hardener was added to the mixture with mixing gently, and The mixture was poured from one corner into the mould (to avoid bubble formation which causes cast damage) and the uniform pouring is continued until the mould is filled to the required level , and The mould was placed on an electrical vibrator to remove any residual bubbles (i.e. captured gas that evaporates during mixing and temperature rise) and to guarantee the distribution of the cast inside the mould . The electrical vibrator show in figure (2).

Figure (2): electrical vibrator

The mixture was left in the mould for (24) hrs at room temperature to solidify. Then the cast was aged for one week to dry off. This step was important to reveal complete polymerization, best coherency, and to relieve residual stresses. The specimens were cut according to the standard dimensions for each test, using different cutting tools. The Tensile test was performed according to (ASTM D638M- 87b) at room temperature [10]. Compression test was performed according to (ASTM D695- 85) at room temperature [11]. Impact test was performed according to (ISO-179) at room temperature [12]. Hardness test was performed by using shore hardness (D) and according to (ASTM D 2240) at room temperature [13]. The water absorption test was performed according to (ASTM D 570- 98) at room temperature [14]. As show in table (1).

Table (1)

Type Device	ASTM	figure Device	Figure specimen	Test type	N
Instron Tensile Test machine.	ASTM-D638-87			**Tensile test**	**1**
Leybold Harris No.36110	ASTM-D695			**Compression test**	**2**
Charpy Tension Impact testing macbines	ASTM-ISO-179			**Impact test**	**3**
Shore(D) Test	ASTM-D 2240			**Hardness test**	**4**
	D 570-98			**Water absorption test**	**5**

3. Results and Discussion
3.1 Mechanical Properties
3.1.1 Tensile Test

Figure (3) shows the relationship between tensile strength with weight fraction for material composite of polyurethane reinforced by (coconut shell powder) in such stress-strain curve, the stress is the average longitudinal stress in tensile sample and can be expressed as [15]:-

$$\sigma = P/A \qquad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where:
σ: average longitudinal stress for specimen (MPa).
P: applied load (N).
A: original cross- sectional area before testing (m^2).

Figure (3) reveals that tensile strength of the prepared composite material, will increase with increase in the weight fraction up to 6%wt, due to the power of high linkage between the matrix material and reinforcement material, which leads to reducing the slip during the tension. Further explanation is that there are particulates easily penetrate the matrix and especially when volume of particulate is small as well as ease of penetration of these particulate in the glades located within matrix material [16]. This will increase the ability of the media on wettability and especially when be the media of liquid material before the completion of the process of hardening of the composite material, the increase in property of wettability between the media and reinforced materials will increase from surface area for interface between the reinforced materials and matrix material and among the reinforced material itself. Composite material supported by particulate does not depend only on the properties of components, but also depends on the nature of the interface between the components and the weight fraction and sometimes on the geometry of the particulate [17]. The value of the tensile strength for the pure polyurethane is (15.5 MPa) and this value had improved when filler of (coconut shell powder) were added which reached its maximum amount (31.3 MPa) at weight fraction of (6%wt).

While the decrease in the tensile strength after the weight fraction of 6%wt , may be due to the bond weakness, as well as the increase in the weight fraction of particulates had made it difficult to penetrate the matrix material when the weight fraction was more than (6%wt). Additions of (coconut shell powder) resulted in further increase in filler amount that will reduce the convergence between the matrix material surface and particulate filler of each other adequately. the process of wetting for surface of particulates by liquid matrix material is incomplete, leading to weakening of the bond between matrix material and the filler material which reduces the efficiency of transfer of load from composite material by the matrix material to particulate and therefore composite material will break at less stresses, In addition to the difficulty of penetration which may weaken the forces of adhesion as well as will create a number of defects within the composite material and this will generate many concentration zones of the stresses that will accelerate from the process of the failure of the sample and making the material behave as brittle material [18].

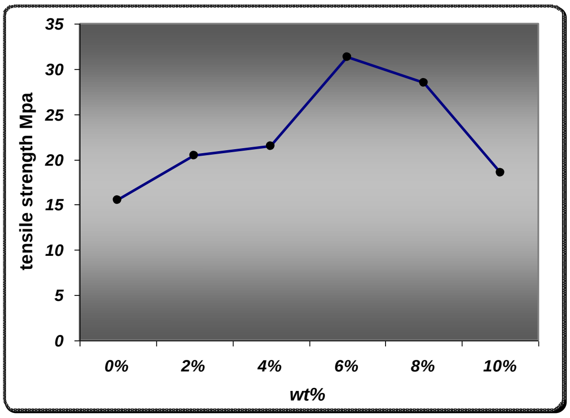


Figure (3) the relationship between the tensile strength and weight fraction for polyurethane resin filled with (coconut shell) powders, at a rang of (2-10) %wt.

3.1.2 Compression Test

Figure (4) illustrates the compression strength of polyurethane base matrix composite filled with (coconut shell powder).

Results had revealed that compression strength had increased when adding (coconut shell powder) filler to polyurethane up to weight fraction of 6%wt, and the maximum values were (53 MPa) compared to the maximum value of compression strength of pure polyurethane had reached to (47 MPa).

Increase in the values of compression strength when adding particulate filler to the composite material may be due to that particulates will impede the cracks movement, while a decrease in compression strength happens when the weight fraction exceeds 6%wt for (coconut shell powder). This may be related to an increase in the viscosity of the liquid at high rates from these particulates, causing difficulty in fluidity for the matrix and penetrate between filler which reduces wetting for filler prior to hardening of the matrix causing adhesion decrease between the matrix and the filler and the emergence of a lot of flaws and gaps within the prepared composite material and eventually lead to lower compression strength at high rates of filler [16]. As is known, adhesion force will decrease significantly with increase in weight fraction of filler [16 and 19].

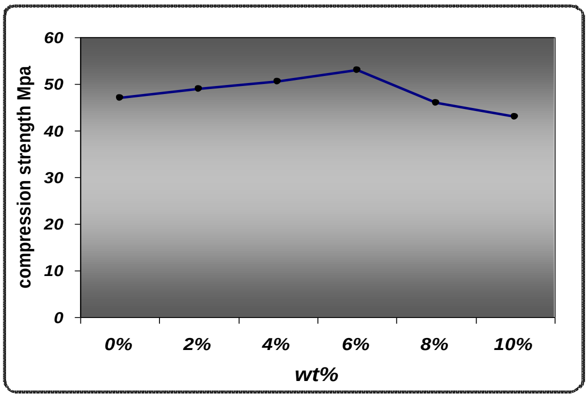


Figure (4): the relationship between the compression strength and weight fraction for polyurethane resin filled with (coconut shell) powders, at a rang of (2-10) %wt**.**

3.1.3 Impact Test

Impact test is used to determine the tolerance range of composite material for impact force through the absorbed energy by these materials to resist this kind of power [20].

The impact test is different from the rest of the mechanical tests because it is very fast, where the specimen will be subjected to the rapid stress leading to change in the behavior of material [20 and 21]. Impact strength is calculated from the following equation [22, 23]:

$$G_c = \frac{U_c}{A} \qquad \text{.................} \ (2)$$

Where:
G_c: Toughness of material (J\m^2).
U_c: Impact energy (J).
A: cross- sectional area of specimen (m^2).

Figure (5) shows the behavior of the prepared composite materials depending on the change of impact energy with the change of the weight fraction. Results in figure (5) revealed that the impact energy (Uc) increases with increasing the weight fraction of (coconut shell powder) up to 2%wt , and reach its maximum amount, i.e. (0.156 J) respectively compared to the impact energy of pure polyurethane (0.15) J. The increase in impact energy may be related to the particulate filler that may act as obstacles that will retard the crack growth in the prepared composite system and this will cause the crack deflection in shape and direction i.e. blunting of crack tip will be expected, then toughness being increased [20 and 24]. While decrease in the impact energy at weight fraction higher than 2%wt, may be related to the bond weakness between the matrix and the particulate filler [16].

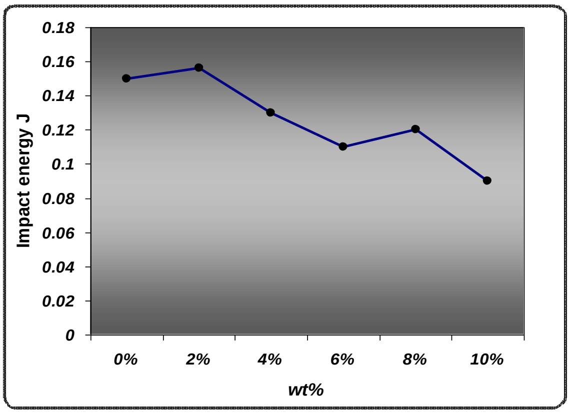


Figure (5): the relationship between the impact energy and weight fraction of polyurethane resin filled with (coconut shell) powders, at a range of (2-10) %wt.

3.1.4 Hardness test

Hardness test types Shore (D) were carried out for polyurethane (PU) before and after particulate filler addition. Figure (6) shows the effect of weight fraction for the particulate addition on hardness.

As shown in fig (6) hardness for the polyurethane will be increase by adding filler, (coconut shell powder) and the hardness will keep increasing with increasing weight fraction, and the concept of hardness can be adopted as a measure of plastic deformation, where material will suffer under the influence of external stress and the addition of particulate filler will contribute in raising the hardness as a consequence of increased resistance to plastic deformation.

Hardness had reached its maximum value at weight fraction of 10% for (coconut shell powder). (82 Shore (D)), compared with the hardness of the pure polyurethane i.e. (70) Shore (D). Results note that Polyurethane increased hardness after adding powder coconut husks and the reason is that it is similar in chemical composition to hardwood composition but characterized very high hardness much more than hardness for wood

Flour because contain on lignin is much higher from cellulose which is less hardness compared to wood flour [24 and 25].

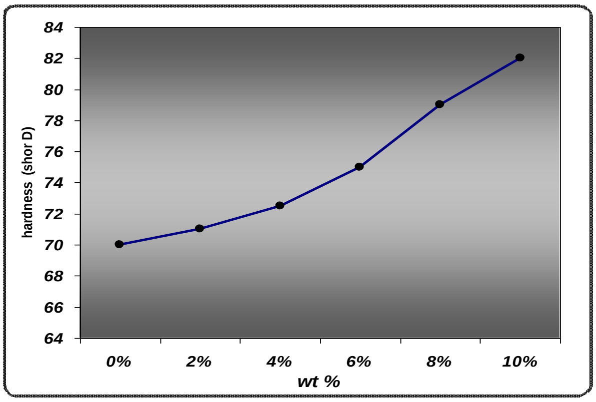


Figure (6): the relationship between the hardness and weight fraction for polyurethane resin filled with (coconut shell) powders, at a rang of (2-10) %wt**.**

3.2 physical properties

The study of the physical properties of materials engineering of things very important and that should be taken into consideration because they determine the validity of the use of these materials for the operations of Fine and operational and that the knowledge and the possibility of measurement plays a big role in the selection of appropriate materials for specific purposes and to overcome the problems that occur during the operation or the formation of these substances, and therefore can introduce a lot of improvements to the polymer chemical and technological ways different.

3.2.1 Water Absorption

Some studies had revealed that mechanical properties such as toughness and resistance will fall after exposure the specimen for moisture, or after absorption of specific quantity of water and the reason for this, is that the moisture has a role in breaking the interface between the matrix material and the reinforced material and by reducing the adhesion between the matrix material and the reinforced material, or the reinforced material may absorb greater amounts of the water, causing swelling of the matrix material and therefore separation in the matrix material will be expected and the detoration of the interface in the composite material will happen and this leads to decreasing in transfer of stress to the filler material and thus lead to decrease in toughness and resistance will be decreased [16 and 25] **.** By immersion of the specimen in water, the water absorption (change in mass) can be calculated according to equation (3) [14]:-

$$\textbf{Water absorption} = \frac{w_2 - w_1}{w_1} * 100 \quad \ldots\ldots (3)$$

Where:
w_1: mass of specimen before immersion (g).
w_2: mass of specimen after immersion (g).

Figure (7) shows the relationship between the weight fraction of particulate filler and the percentage of water absorption, where we note an increase in the value of absorption slightly when filler of (coconut shell powder) were added to the polyurethane. The reason for this is that these materials have low absorption coefficient. No enhancement was observed in decreasing the water absorption % when filler within scope of our work were added (coconut shell powder) , compared with water absorption of the base polymer matrix of polyurethane i.e.(0.137%) , where we note an increase in the value of absorption with the increase in weight fraction for the filler.

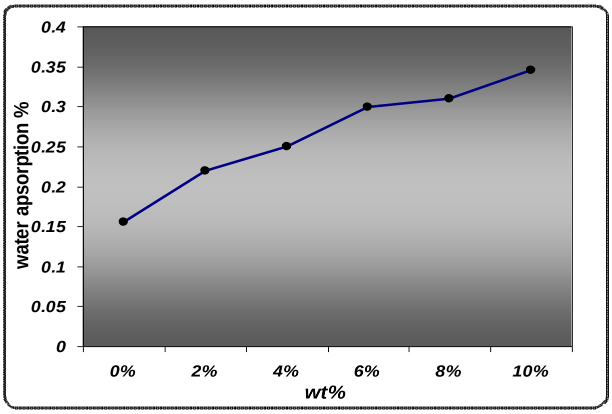


Figure (7): the relationship between the water absorption percentage and weight fraction for polyurethane resin filled with (coconut shell) powders, at a rang of (2-10) %wt.

4. Conclusion

Tensile test results had shown that tensile strength has increased with increasing weight fraction of (coconut shell powder) filler particles and reached their maximum value at (6 % wt). Furthermore, the increasing weight fraction revealed decreasing properties of the prepared system.

Also results had shown that compression strength and impact energy increased with increasing weight fraction of (coconut shell powder) up to 6%wt, while further increase in weight fraction revealed a decrease in the properties of the prepared system. Hardness test results had shown that hardness increase with increasing weight fraction of (coconut shell powder) filler particles and reached their maximum value at (10 wt %) of addition. The water absorption percentage as a physical property for the prepared composite material had shown an increase with increasing weight fraction of (coconut shell powder) filler particles. The improvement of polyurethane resin with (coconut shell powder) filler particles had shown greater values for the fore-mentioned properties than the improvement of polyurethane resin with (coconut shell powder) filler particles, except for hardness value.

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تأثير إضافة مسحوق قشور جوز الهند على خواص مادة متراكبة ذات أرضية بولي يورثان

حيدر عباس صلال
المعهد التقني /كوفة

الخلاصة:

يركز هذا العمل على تحضير مواد متراكبة ذات أساس بوليمري بطريقة (الصب اليدوي)، ودراسة تأثير الكسور الوزنية المختارة (2 , 4 , 6 , 8 ,10) % من (مسحوق قشور جوز الهند) على خواص المواد المتراكبة المحضرة، حيث المادة المتراكبة من راتنج البولي يورثان (PU). عدد الاختبارات الميكانيكية التي أجريت لتقييم النظام المتراكب المحضر تتضمن (الشدّ، الانضغاط، الصدمة والصلادة)، بالإضافة إلى الاختبار الفيزيائي (النسبة المئوية لامتصاصية الماء)، وكل الاختبارات أجريت في درجة حرارة الغرفة.

النتائج القصوى لمقاومة الشد ومقاومة الانضغاط وطاقة الكسر والنسبة المئوية لامتصاص الماء كانت ((MPa 31.3)، (53 MPa) ، (J0,156)،(Shor (D)82)، (0.345%)) عند (2% wt, 6 % wt , 6 % wt , 10 % wt, 10 % wt) على التوالي .تحسنت الخواص للعينات المقواة عن العينة النقية حيث أن مقاومة الشد ازدادت حوالي الضعف ومقاومة الانضغاط بمقدار 12% وطاقة الكسر بحدود 4% والصلادة بمقدار 17% والنسبة المئوية لامتصاص الماء الى الضعف .