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Study of Polymeric Composite Reinforced with Natural Particles: Measurement and Evaluation

Jawad K. Oleiwi*, Rusul S. Hadi

Materials Engineering Department, University of Technology, Baghdad 10066, Iraq

Corresponding Author Email: 130041@uotechnology.edu.iq

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ABSTRACT

Natural particles and their composites are important in materials science, where a significant attentiveness is being displayed in the usage of natural particles as reinforcement in polymer composites. The purpose of this research is to investigate the effect of the walnut shell particles as reinforcing fillers in a matrix composite. So, the amount composite examples were advanced through varying the percentage by weight of filler (3, 5, 7, and 9%) in an epoxy and unsaturated polyester polymer. Composite samples were mechanically characterized by tensile tests, flexural tests, hardness tests, and the Izod impact test. The tensile strength and impact strength of epoxy resin were increased after adding organic waste filler. The highest values of tensile strength and impact strength happened at 7% wt. The flexural strength and hardness of shore D increased with the percentage of walnut shell particles. The highest values of flexural strength and hardness were found at 9% wt. The results show that the mechanical properties of epoxy composite are better than the mechanical properties of unsaturated polyester composite when walnut shell particles are added.

1. INTRODUCTION

Composite materials are materials that result from two or more different materials being physically and chemically mixed in order to get a new material with good physical and mechanical properties. The composites have many properties and advantages, such as lightness, stiffness, bending strength, and low coefficient of thermal expansion, making them suitable for use in many complex and advanced applications [1]. The composite material consists of two main parts: the matrix material, which includes materials (metal, ceramic, and polymer); and reinforcing materials of various shapes, which can be fibers, powders, flakes, particles, fillers, or wool depending on the required application. Reinforcing material improves the mechanical properties of the durability, stiffness, and toughness of the matrix material, provided it forms a strong bond between them [2, 3].

Epoxy resin is thermosetting solid, with high-performance, easy-to-process polymers. It contains at the very least two epoxy groups per 1-3 molecule. An epoxy ring is made up of two carbon atoms joined by a single covalent bond to an oxygen atom with a C-O bond angle of 61° 24' [4, 5]. Because of their excellent adhesive properties, reactive epoxy rings can be used in a wide range of applications. Hardness, chemical resistance, dimensional stability, specific resistance, and the great fluidity before hardening allow this easy operation [6, 7]. However, the treatment method causes permanent changes in the physical and chemical properties of the hardener and resin. Because of the creation of extremely cross-linked polymer, the resulting epoxy resin is usually unstable, has little resistance to the propagation of cracks, and is brittle [7-10].

Natural fibers, for example, wood, jute, flax, hemp, and many other cellulosic waste resources have been utilized as a correct replacement for artificial fibre reinforcement for composites in several uses. Those fibres showed special advantages, for example, low pollutant emissions, little density, biodegradation, low cost, and high specific properties. In addition, compounds made from environmentally friendly materials (like biodegradable materials) are getting a lot of attention for a number of interesting applications [11, 12].

Al-Waily [13] proposed a resolution for dynamic analysis of hyper-composite plates joined from double reinforcement fiber, short plus ash or mat plus ash, with an epoxy or polyester resin matrix. The types of reinforcement fibre plus matrix resin the effects of the volume fraction were studied theoretically. The results showed that the normal frequencies rise through the rising of reinforcement fibres augmented by the resin matrix or the rising of high-strength reinforcement fiber.

Talikoti et al. [14] focused on utilizing walnut shell ash as a reinforcing material of a thermosetting kind of polymer called Bisphenol-A as the matrix material. Walnut shell ash of 5% by weight was added to the epoxy resin to make the composite test samples. The manual winding technique was utilized to manufacture the composite. The composite samples were made according to ASTM standards, and various tests, such as bending and tensile exams, were completed so as to measure the mechanical properties of the composite. The addition of walnut shell ash to the epoxy increased the flexural, tensile, and compressive strengths by 10.4%, 17.6%, and 42%, respectively.

Oleiwi et al. [15] examined the effect of the addition of natural ash of pistachio shell to PMMA, which is utilized in denture use. The addition of ash in altered weight fractions (3%, 6%, 9%, plus12%), plus various average grain sizes (53µm, 106 µm, 150 µm, and 212µm %), also examining surface hardness, density properties, and compression strength.

The greatest values of surface hardness and compression strength in PMMA composite examples occurred at (9%wt.) of the weight of the filler grains. Furthermore, the results indicated the density rates for the samples are raised through the rising weight fraction of the filler particles.

Ahmad and Ahmed [16] investigated the use of agrarian remains shell (walnut and pistachio) as a filler in epoxy resins as an alternative to plastic and wood-based ingredients. These samples were characterised by double sets of composite materials that contained epoxy resin by way of a material matrix strengthened by pistachio shell ash and walnut shell ash through various weight ratios (11%, 15%, and 19%). Mechanical tests (impact, bending, hardness) and physical tests (absorption, thermal conductivity) were created. The results showed a development in the bending strength, hardness, and impact resistance when adding the minutes of the pistachio at the addition ratio of 19%. On the other hand, physical measurements revealed a small rise in the rates of absorption and thermal conductivity.

Although, the unsaturated polyester resin and epoxy have good advantages make for appropriate industrial applications. But it has low mechanical properties compared with the composite, which represents its main drawbacks of it. So many tests had been done in order to overcome these problems. As expected for the composite materials, the effect of the reinforcing natural particles will increase some of the mechanical properties of the used polymers. The main aim of the present work is to estimate the tensile strength, impact strength, hardness shore D properties, and flexural strength of unsaturated polyester resin and epoxy after reinforcing by walnut shell particles in various weight fractions.

The layout of this article is represented by 2. Experimental design, 3. Mechanical tests and 3. Conclusions.

All the above researchers studied the effect of adding different natural fibers and particles to PMMA and other polymers. But this article deals with reinforcing epoxy and unsaturated polyester with walnut shell particles with certain particle size and different weight fractions.

2. EXPERIMENTAL DESIGN

2.1 Materials

In the current study, walnut shell particles were used, which is a natural material, in addition to the epoxy and unsaturated polyester resin matrix. Tables 1 and 2 show the physical and mechanical properties of the unsaturated polyester resin and epoxy matrix that were utilized in this research [17, 18].

Table 1. Characteristics of unsaturated polyester used in [17]

Tensile strength	65 MPa
Young's Modulus (GPa)	2.06-4.41
Percent elongation	<2.6
Fracture Toughness	0.6 $MPa.m^{1/2}$
Density	1.11 gm/cm^3

Table 2. Characteristics of epoxy resin used in [18]

Tensile strength	25 MPa
Young's modulus	1.060GPa
Flexural strength	53 MPa
Compressive strength	50 MPa
Viscosity	0.5-1.0 poise
Density	1.1gm/cm^3

2.2 Particle size analyzes

The particle size dispersion of the walnut shell particles matches the quantity of material that stayed on a sieve with a stated mesh size. Based on the analysis, it was found that the filler made by the company was divided into groups of about the same size. The study of the results allowed determining that the size of the majority of the found particles was 300 µm by the mastersizer device.

These weight fractions of reinforcing materials are considered within the strengthening limits of the previous literature review, but for different natural reinforcement materials. Also, the particle size within 300 µm represents the optimum particle size obtained in a larger quantity used as a reinforcement material to evaluate some mechanical properties.

2.3 Chemical composition

The chemical composition of the walnut shell particles utilized in this study is shown in Table 3. They comprise high iron (Fe) content, potassium content, and calcium content.

Table 3. Chemical composition of walnut shell grains

Element	Concentration
Fe	0.1033
K	0.0645
Ca	0.05043
Na	0.045
Cl	0.02622
Ba	0.01334

2.4 Methods

The walnut shell material was ground with a ball mill to obtain the required granular size. Then the sample was prepared by mixing the powder with the epoxy and unsaturated polyester in several ratios, which are 3, 5, 7, and 9% wt, and it was mixed with a glass mixer for 15 minutes, The mould used in this process is made of rubber and is coated with a layer of wax to ensure that adhesion is not obtained between the composite material and the mould, after which the hardener was added and mixed for 15 minutes, and then the manual moulding process was performed and left to dry for 24 hours, and then it was dried at 55 degrees Celsius for two hours. The composition of sample polymer composite materials is shown in Table 4.

Table 4. Composition of example polymer composite materials

Example	Composition
1	100%Matrix materials (Epoxy or polyester resins)
2	97% Matrix+3% Powder
3	95%Matrix+ 5%Powder
4	93%Matrix+ 7% Powder
5	91%Matrix+ 9% Powder

3. MECHANICAL TESTS

3.1 Tensile properties

Figure 1 shows the results of the ultimate tensile strength. It is apparent that the additive of reinforced powder in epoxy composites promotes the tensile strength of the advanced composites. This could be caused by enhanced filler matrix adhesion and, furthermore, caused by the stiffness of powder [19]. This enhancement of tensile properties demonstrates that the tough interface contact is advanced via the hybridization phase amongst the walnut shell particles and epoxy or polyester resin. The tensile strength for epoxy composite was reduced from 36.57 MPa to 32.98 MPa and the tensile strength for unsaturated polyester was reduced from 31.32 MPa to 22 MPa by adding 9% wt. of walnut shell particle to the matrix.

The reasons behind such behavior are the high tensile strength at 7% wt is due to compatibility between the matrix and natural reinforcing particles, and the formation of supramolecular or cross-link bonding which shields or covers the natural particles, and this, in turn, prevent the propagation of the cracks inside the material, as well as the owing to weak bonding between resin and filler which supported micro-cracks throughout the example composite loading at 9% wt [20, 21]. The results of the tensile strength of pure unsaturated polyester resin are smaller than other samples with weight fraction (3%, 5%, 7%, and 9%), so the addition of 7% weight fraction of walnut shell effects positively on tensile strength and enhances the tensile strength. This is because of the tensile properties, perhaps dependent on some features, for example, the filler content relatively than the grains-matrix interface plus the stiffness of the reinforcing grains [22, 23].

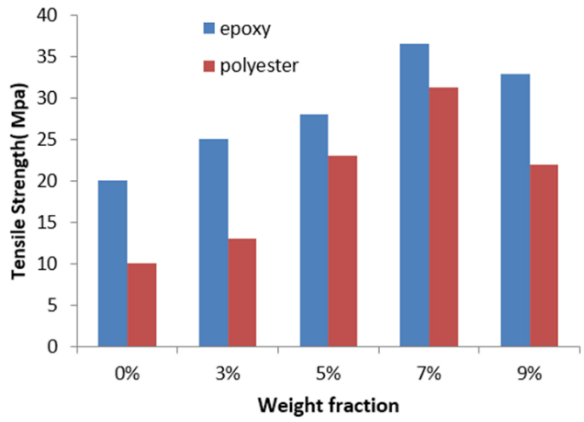

Figure 1. Tensile strength of the samples

3.2 Impact strength

Figure 2 shows the results of the impact strength of all samples. graphical exhibition, a steady increase in impact strength by the addition of walnut shell particles. The highest value of impact strength was 53.245 KJ/m^2 for epoxy without the addition of (7% Wt.) walnut shell particles. As shown in Figure 2, the addition of walnut shell increases the ability of the composite material to absorb the impact force. Increased impact strength may be due to strong humidification of particles due to high epoxy resin content. While the impact strength of pure unsaturated polyester is lower than other composite samples, the addition of (3%, 5%, 7%, and 9% wt.) walnut shell particles cause a positive in-bearing impact load plus increases the impact energy wanted to fracture the sample. This might be caused by the creation of a void which guides to crack propagation, resulting in whole detachment between strengthening and matrix material and therefore results in less energy absorption [24].

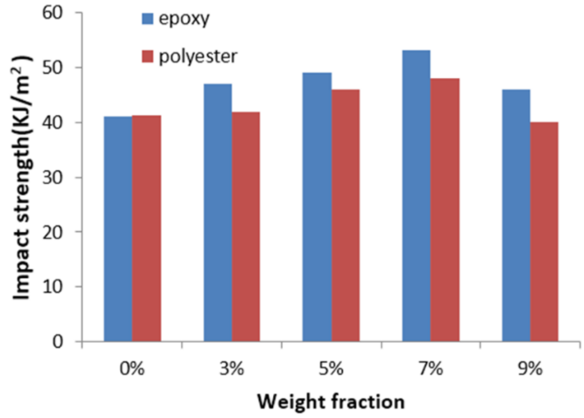

Figure 2. Impact strength of the samples

3.3 Flexural properties

Figure 3 shows the addition of walnut shell particles to the matrix material has improved flexural strength compared to the epoxy without addition. The highest value for the epoxy composites reinforced by walnut shell particles was (1200 MPa) at a ratio of 9% wt. The reason that could be credited to the raised flexural strength is that the additive (9%) results in certain improvements to the adhesive properties of the composite through improving the mechanical joining between epoxy and filler and thus improving the stress transfer via a used load [25, 26]. Flexural strength results for samples made of pure polyester resin are smaller than those of other samples.

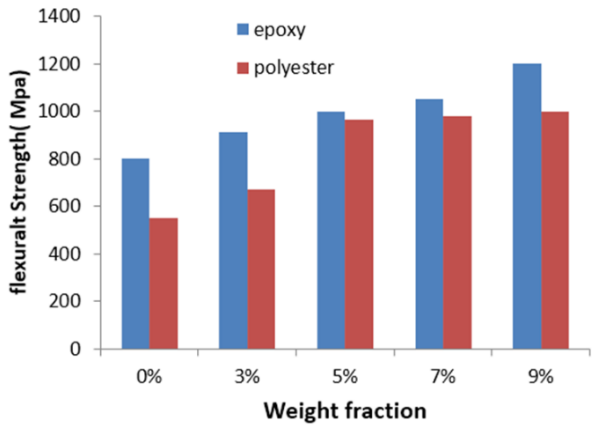

Figure 3. Flexure strength of the samples

3.4 Hardness test

The capability of a material to withstand indentation, localized and penetration plastic deformation is described by methods of hardness shore (D). The values of all the samples are shown in Figure 4. It could be that samples of polymer composites strengthened by (9%wt.) powder with epoxy and unsaturated polyester have a higher value of hardness shore (D) as compared with pure samples. The first reason is that a matrix carries some stress applied to the particles, which transfers part of the load. This is the second reason: Walnut shell fragments contain particles that make the surface of polymer compound materials harder. In this case, the maximum hardness shore D values for composite epoxy and composite unsaturated polyester, respectively, were (89) and (87) [27].

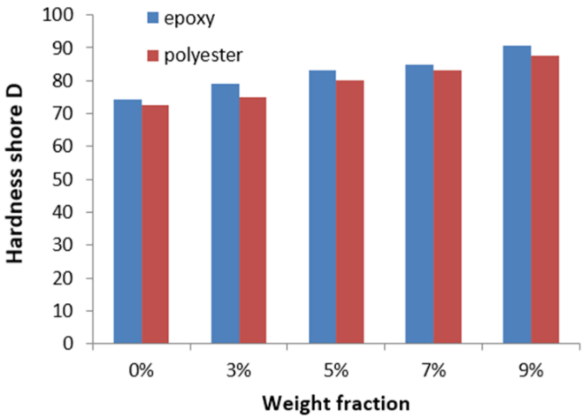

Figure 4. Hardness test of the samples

4. CONCLUSIONS

After mechanical tests were carried out on the prepared composites, which consist of unsaturated polyester and epoxy as a matrix reinforced with (3%, 5%, 7%, and 9% wt.) walnut shell particles, the following conclusions were reached in this study:

1. This study contributed to improving the mechanical properties by 7% of reinforcement which is a choice of the best composite material to be an alternative to the unreinforced epoxy or unsaturated polyester that is useful for certain industrial applications.
2. The highest values of tensile strength and impact strength of the composite epoxy were (36.57 MPa.) and (53.245KJ/m^2) with the addition of (7%wt.) of walnut shell particles.
3. The highest values of the flexural strength and hardness for the epoxy composite happened at 9% wt.
4. The results of mechanical properties of the epoxy composite higher than of unsaturated polyester composite.

The limitation and future research are represented by studying other natural materials may be nanoparticles or woven natural fibers and studying other mechanical properties like fatigue and creep under static and dynamic loading.

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