Design Engineering

ISSN: 0011-9342 | Year 2021
Issue: 7 | Pages: 2648- 2663

Manufacture of wood processor from unsaturated polyester foam and walnut husk waste

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Abstract

A polymeric adhesive made of unsaturated polyester resin was used in the recycling of walnut husk waste for the purpose of manufacturing a wooden furniture processor (0, 2.5, 5, 7.5, 10, 12.5, 15)% and with a grain size (45) µm of walnut shell granules, tests were conducted to study some mechanical properties (tensile, bending, shock, hardness) and thermal conductivity in addition to the surface morphology of all samples.

The results of the tests showed an improvement in the mechanical properties, and these properties were enhanced with an increase in the weight fraction of the walnut husk granules. The results also showed a decrease in the thermal conductivity with an increase in the weight fraction of the reinforcement material.

Keywords: Exploiting environmental waste, Walnut Shell, Unsaturated Polyester, and Wooden furniture processor.

1. Introduction

The effective role of engineering materials that enter into various fields of industry has attracted the attention of designers and engineers, so those materials were selected and manufactured with design and construction structures that are consistent with the need, functionality and the ability to analyze their failures, as structural mechanical engineering seeks to form structures with durability, strength, resistance to corrosion, and reflecting its aesthetics [1]. Polymers have many advantages over other materials, mainly due to the unique combination of hydrogen and carbon atoms. This combination makes the polymer extremely versatile and extremely durable to intense sunlight in summer, very low temperature in winter and humidity in rainy season. It is also unaffected by any of the Microorganisms have a long life. With all these properties, petroleum-based elastomers have been used in various applications especially when strength is not of much concern [2].

ISSN: 0011-9342 | Year 2021
Issue: 7 | Pages: 2648- 2663

The widespread use of plastic materials has created a serious environmental, economic and social problem where finding disposal sites for plastic-based materials is a major challenge [3]. With this problem, the use of biodegradable materials in the form of fibers or particles or combinations thereof as reinforcing materials in polymeric matrix has been increased since the last decade. Natural fibers and fillers offer different advantages over other synthetic or conventional fillers and fibers. The various technical, financial and environmental benefits offered by natural hardeners are numerous as they are easy to provide, low cost, high strength-to-weight, easy to process, biodegradable, and environmentally friendly [4].

1.1 Composite Materials

Compound materials consist of two or more materials with different composition or shape, and physical interlocking occurs between these materials to obtain a new multi-phase system where the compound material is not described as one of its compounds [5].

Many compound materials consist of only two phases, one of which is called the base phase (Matrix) and this phase may be polymer, metal or ceramic and surrounds the other phase called the reinforcing phase and this phase is in the form of particles, sheets or fibers that are immersed in the base material , The properties of the overlapping materials are a function of the properties of their constituent phases, their relative amounts, and the geometrical shape of the phase [6]. The composite materials possess good features and properties such as toughness, strength, low density, good thermal and electrical insulation, in addition to being easy to form [7].

1.2 Pollution

The bio-economic strategy launched by the countries of the world and the transition to a stronger, circular and low-carbon economy has imposed new procedures and requirements towards greater and more sustainable use of natural resources and the transformation of their waste into value-added products. or partially from materials of biological origin other than fossilized materials can make the economy more sustainable and reduce its dependence on fossil fuels since they are derived from renewable raw materials such as plants.

Bio-products can help reduce CO2 and also have other advantages such as low toxicity and are also cost effective and have very good advantages in terms of bonding performance, mechanical properties, thermal stability and water resistance, and because most industrially used wood adhesives consist of formaldehyde which is a compound Highly reactive, in 2004 it was reclassified from a probable human carcinogen to a known human carcinogen by the International Agency for Research on Cancer, which represents one of the major drivers of change of scientific and industrial interest from traditional formaldehyde-based synthetic resins to new bioadhesives for production and processing. Environmentally friendly wood compounds [8].

ISSN: 0011-9342 | Year 2021
Issue: 7 | Pages: 2648- 2663

Recently, the demand for biodegradable materials made from renewable resources has increased due to the high prices of raw materials, especially those obtained from the oil and natural gas sector, and environmental concerns related to non-renewable resources. It is estimated that many synthetic polymers require 50 years To completely decompose, polymeric waste poses a major threat to the environment due to its non-degradability and microbial resistance [9]. In the context of the economic recycling of waste and the reuse of waste in industry or for energy production, many studies and research have been conducted on agricultural wastes that depend on wheat straw, rice straw, hemp husks, sunflower stalks and walnut husks due to the ability of these materials to biodegradation and renewal in addition to their outstanding mechanical and physical properties The fruitful walnut tree (Ayn al-Jamal) is one of the agricultural products that opened a promising horizon for the effective use of agricultural resources in ridding the environment of pollution caused by industrial polymers, in addition to its other advantages [10].

1.3 Walnut Shell:

Among the many natural fillings, edible nut shells and ground nut shells have gained attention in the past few years. In this paper, peanut shell, almond shell, coconut shell, hazelnut shell and walnut shell are of interest. Among the various shell powder used as fillers in polymeric resin, walnut shell was found to be a less explored area.

Walnuts are an important crop for edible nuts in temperate regions, after China, Iran ranks second in nut production, and walnut production worldwide in 2020/2019 reached nearly (965,400) tons, taking into account that the shell of the walnut fruit represents what Approximately 67% of the total weight of this fruit leaves about (646,818) tons of nut shells every year, especially in China, Iran and Turkey [11]. Walnut shells are agricultural waste that is available in large quantities, and can show high hardness and hardness, and such agricultural by-products have many encouraging advantages, including low costs and abundance, and their ability to biodegradation, and renewal, in addition to wide flexibility and sound insulation and have multiple advantages that make them of interest to In terms of cost, durability and outstanding flexibility in addition to that it does not leave any scratches or pits during cleaning and is environmentally friendly, and its availability as a renewable resource is an additional advantage [12].

1.4 Aim of the Research:

1- Study of manufacturing a wood processor from environmentally friendly materials (walnut shells) using a polymeric adhesive (UPS).

2- Study of some mechanical properties and thermal conductivity of the wooden processor.

2. Materials and Experimental Work:

Walnut husk waste (WS) was used after cleaning and grinding with a granular size of 40µm and mixing and mixing well with weight fractions (0, 2.5, 5, 7.5, 10, 12.5, 15)% with unsaturated polyester (UPS) polymeric adhesive manufactured by the company. (SIR) Saudi Arabia It is one of the thermosetting polymers and it is in the form of a transparent viscous pink liquid at room temperature and mixed with the hardener in an amount of 2 g per 100 gm of (UPS).

The composite materials were prepared from walnut shell granules (WS) with the above weight fractions and mixed with the polymeric adhesive (UPS) by (manual casting) in molds prepared for this purpose in order to obtain samples of sizes and shapes according to the international standard (ASTM) and heat treatment in an oven at (50 C°) for a period of (45 min).

3. Mechanical Tests:

3.1 Tensile Test:

The tensile test is widely used to provide the designer with adequate information about the nature of the material, its resistance, maximum stress, elongation and other engineering information. The tensile test of a sample is carried out by applying a continuous increasing axial force with continuous observation of the elongation of the sample and then creating the geometric curve between the strain and stress (Strain-Stress Curve) whose values consist of the values of the applied load and the values of the elongation obtained in the sample.

In the (stress-strain) curve, the stress that is used is the average longitudinal stress in the tensile sample (Average Longitudinal Stress), which is extracted from dividing the load by the original cross-sectional area of the sample [13].

$$\sigma = \frac{P}{A} \qquad \text{......... (1)}$$

(Mpa): The longitudinal stress rate of the sample "σ"

(N): applied load "P"

(m2): The cross-sectional area of the original sample before the "A" test was performed.

The strain used in the (strain-strain) engineering curve is the average linear strain, which is extracted by dividing the elongation obtained for the sample by the original length of the sample [13].

$$\varepsilon = \delta / L^\circ \qquad \text{......... (2)}$$

ε: agitation

Design Engineering
ISSN: 0011-9342 | Year 2021
Issue: 7 | Pages: 2648- 2663

δ: the elongation of the sample (m)

L°: original length (m)

Note that (δ) is equal to the difference between the final length ("L") and the original length (L°).

$$\delta = L - L_{\circ} \qquad \ldots\ldots\ldots(3)$$

The international standard dimensions of tensile test samples are shown in Figure (1-a) and tensile strength test samples are shown in Figure (1-b). Using a tensile testing device, the applied force was recorded in N units and the elongation ΔL in units mm, and using the device plotter, it was obtained direct results were used in drawing the shape of the curve, where the tensile test was carried out in the case where the applied stress is parallel to the test sample [14].

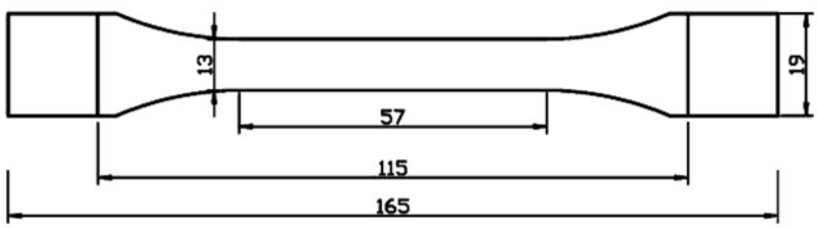

Figure (1-a) Scheme of tensile test samples according to international standards (ASTM D-638).

Figure (1-b) Tensile strength test samples before and after examination.

3.2 Hardness Test:

Figure (2-a) Schematic diagram of the hardness test samples according to the international standard dimensions (ASTM), the samples are Figure (2-b) before and after the test, using the Shore-D device, the device consists of a needle-shaped stitching tool and the stitching tool penetrates inside The sample surface under the influence of a certain load will deviate the pointer of the counter installed in the device, and this deviation represents the amount of hardness of the sample surface.

ISSN: 0011-9342 | Year 2021
Issue: 7 | Pages: 2648- 2663

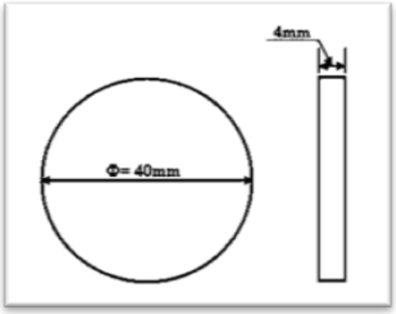

Figure (2-a) Scheme of Hardness and Thermal Conductivity Test Samples According to International Standards (ASTM D-2240).

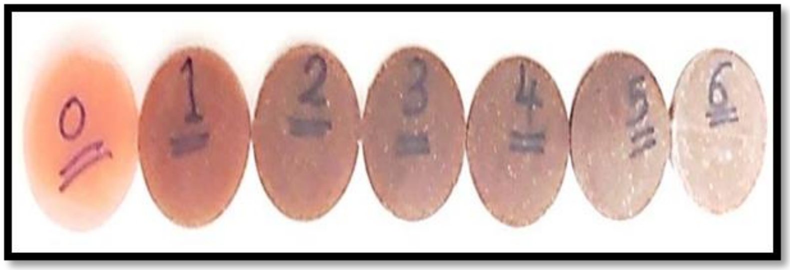

Figure (2-b) Thermal conductivity and hardness test samples

3.3 Impact Test:

Schematic diagram of the shock resistance test samples Figure (3-a) according to the international standards and the test samples before and after the examination Figure (3-b). The shock resistance test is a measure of the strength of materials and their resistance to breaking under the influence of stresses at high speeds.

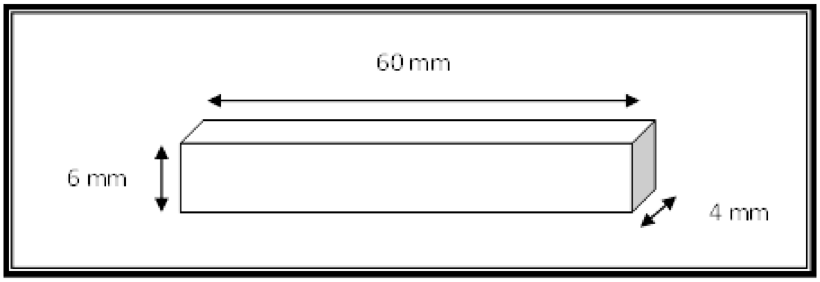

Figure (3-a) Scheme of shock resistance test samples according to international standards

ISSN: 0011-9342 | Year 2021
Issue: 7 | Pages: 2648- 2663

Figure (3-b) Shock resistance test samples before and after the test.

3.4 Bending Test:

The samples were prepared according to the international measurements Figure (4-a) and the examination was carried out using a three points bending device, in which the sample rests from its two ends on two anchors, and a load is applied gradually at the top of the middle of the test sample. We can know the behavior of the material when subjected to increased loads through the amount of bending or deflection (deflection) of the sample. Which can be known through the indicator of the deviation scale (Dial Gauge) located at the bottom of the interface of the device, as the indicator is in its zero position before loading and with increasing load, the deviation increases gradually and the reading of the indicator increases with the increase of curvature. And after the examination.

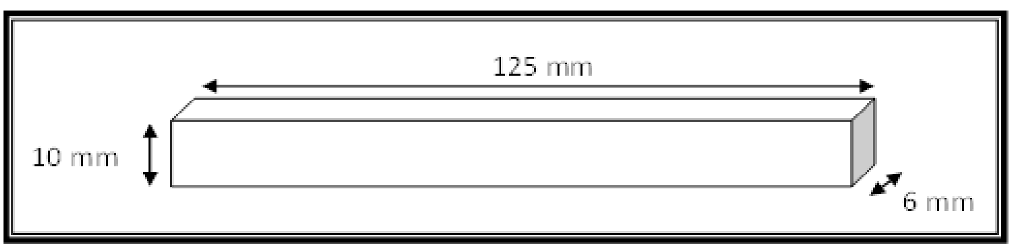

Figure (4-a) Bending Strength Samples Chart According to American Society for Testing Materials (ASTM D-790).

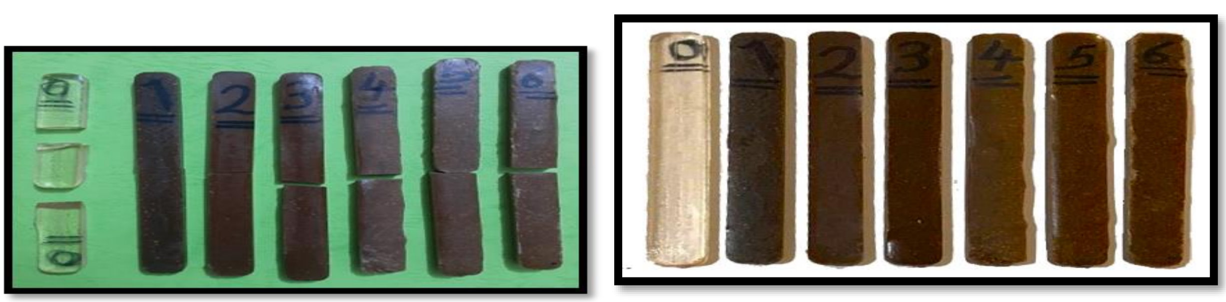

Figure (4-b) Bending resistance test samples before and after the test.

4. Thermal Conductivity Test:

Thermal conductivity (K) is a measure of a material's ability to conduct heat, in poorly conductive materials or insulating materials such as polymers. Thermal conductivity can be calculated using Lee's disk method. Figure (5) is a diagram of the device used to measure thermal conductivity [15]. The device consists of three copper discs and their surfaces are polished to an equal degree to give them the same emissivity and an electric heater. The principle of the device's work depends on converting electrical energy into thermal energy for the disk (H) that represents the heater. Between the other two copper discs and the discs' temperature using standard thermometers, and when the thermal equilibrium state is reached, the temperature of the three discs (Ta, Tb, Tc) is measured and then the thermal conductivity can be calculated.

In this test, the used copper discs must be completely clean and free from any rust that may hinder the conduction, and they must be tightly bound to ensure heat transfer through them. It hinders the conduction and that these disks have the best cohesion and it is important to polish these disks to give them the same emissivity. ("d" _"s") represents the thickness of the sample whose thermal conductivity is to be measured and ("d" _"A" "," d" _"B" "," d" _"C") is the thickness of the discs The three, and the device is placed in an isolated place to stabilize the surrounding temperature, and through the DC Power Supply, the heating coil is equipped with heat, and after the two disks (B, C) reach the state of thermal equilibrium, the temperature of the disks is recorded (TA, TB, Tc) and find thermal energy

passing through the coil, from which the thermal conductivity can be calculated from the following relationship [16]:

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

(e): represents the thermal energy passing through the disk area per second and its units (W/m2k), and it can be calculated from the following relationship:

$$H=IV=\pi r^2e(T_A+T_B)\left[d_AT_A+d_s\frac{1}{2}(T_A+T_B)+d_B+T_B+d_cT_C\right]\ldots\ldots\ldots(2)$$

whereas :

H : the time average of the power applied to the heating coil,

(TA, TB, Tc): Tablet temperature (C°).

(dA, dB, dC): the thickness of the copper discs (mm).

ds: thickness of the model.

ISSN: 0011-9342 | Year 2021
Issue: 7 | Pages: 2648- 2663

I: the current in the circuit (Ampere). V: circuit fitted voltage (Volt).

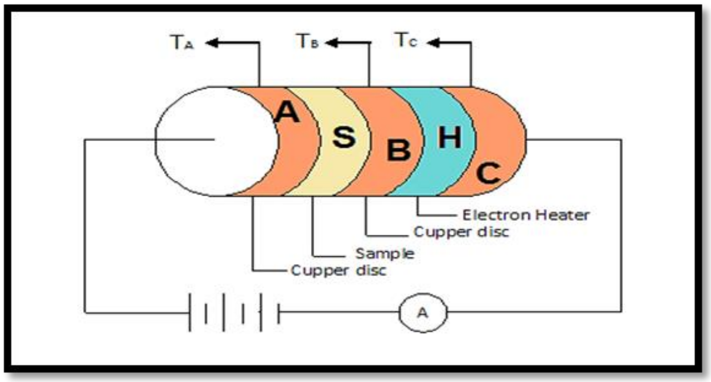

Figure (5) Thermal conductivity test schematic according to (Li disk)

5. Results and Discussion

Table No. (1) shows the results of mechanical tests and thermal conductivity test values for wood processor samples and the change of these values with the increase in the weight fraction of walnut husk particles.

Table (1) Results of mechanical and physical tests for wood processor

Sample No.	Weight Fraction (W S %)	The values of mechanical and physical tests with the weight fraction of walnut shell particles.				
		Tensile Strength (MPa)	Hardness (N/mm^2)	Impact Strength (kJ/m^2)	Bending Strength (MPa)	Thermal Conductivity (W/m.C$^{\circ}$)
0	0	50	80	0.2	60	0.81
1	2.5	55	81	0.2	63	0.79
2	5	58	81.8	0.25	65	0.73
3	7.5	61	82.4	0.28	66	0.69
4	10	64	82.8	0.32	68	0.64
5	12.5	59	83.2	0.35	70	0.6
6	15	55	84	0.4	71	0.56

5.1 Tensile test:

The tensile strength values of the samples of the wooden processor in Figure (6) showed an increase in these values with an increase in the weight fraction of the walnut husk granules compared to (UPS) before reinforcement. In bearing stress, these walnut shells possess high tensile strength and flexibility, in addition to their uniform random distribution within the unsaturated polyester resin and the ease of resin penetration between the walnut shell granules, which generates complete interfaces between the resin and walnut shells [17]. The results also showed that the highest value of the tensile strength of (50 MPa) was observed at the weight fraction 10% and then returned to a decrease, due to the viscosity of the polymeric liquid, which reduces the wetting of the grains before the solidification of the overlapping material and leads to poor cohesion between the polymer and the walnut shells and thus a decrease in the values of the strength Tension after weight fracture 10% of walnut husks [18].

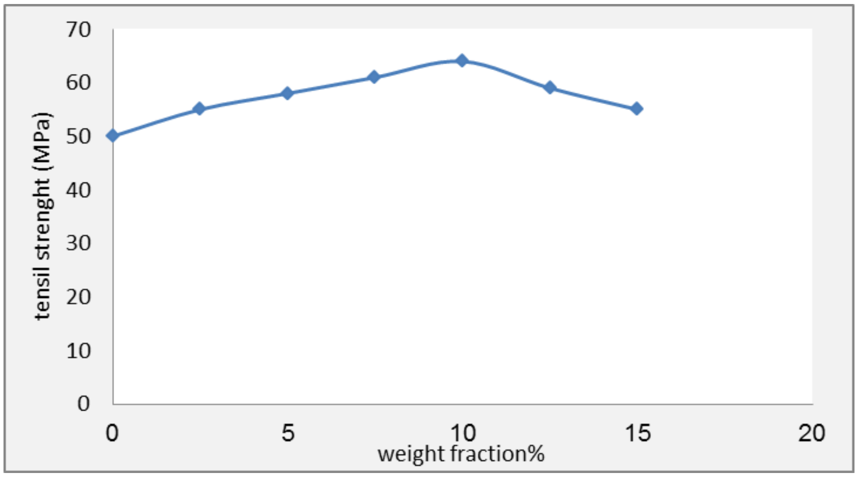

Figure (6) Effect of the weight fraction of walnut shell particles on the tensile strength values

5.2 Hardness Test:

Figure (7) shows the effect of increasing the weight fraction of walnut husk granules on the hardness values. In bearing the stresses imposed on the composite material, as these granules have high strength and hardness, which in turn leads to the hardness of the composite material, and the granules act as an obstacle to deformation of the base material, in general, the use of granules as fillers improves the hardness of the product, especially when using granules with a size less than 50 microns [19]. Because the small-sized particles easily penetrate into the base material and into the pores and interfacial spaces that are likely to form during the sample preparation process, thus increasing the contact area between the components of the composite material and increasing the interconnection between its components in an integrated manner and gives more positive values when testing the hardness, which can be considered a measure of deformation The plasticity that may occur in the material as a result of an external influence, and therefore the addition of granules leads to an increase in the hardness of the material due to its resistance to plastic deformation [20].

ISSN: 0011-9342 | Year 2021
Issue: 7 | Pages: 2648- 2663

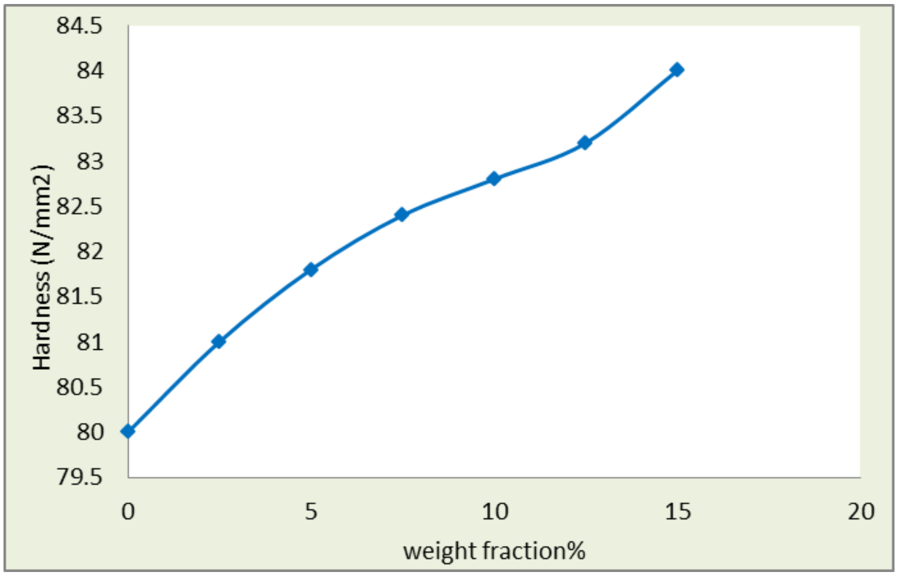

Figure (7) Effect of the weight fraction of walnut shell particles on the hardness values.

5.3 Impact Strength Test

Through figure (8), we notice an increase in the values of the shock resistance of the samples of the wood processor with an increase in the weight fraction of the walnut shell granules due to the granules possessing high shock resistance and high durability compared to the pure polymer adhesive (UPS), which is a fragile polymeric material and easy to break into small pieces. The continuous increase in the breaking energy of the samples of the wood processor is due to the bearing of the walnut shell granules as part of the shock force. For the crack to progress and for the crack to continue growing and bypassing the barriers, it will have to change its shape, transforming into a group of small secondary cracks in an attempt to pass between the grains, and this will lead to an increase in the crack surface and this requires an increase in the energy needed to obtain the fracture as a result of the increase in the crack surface [21].

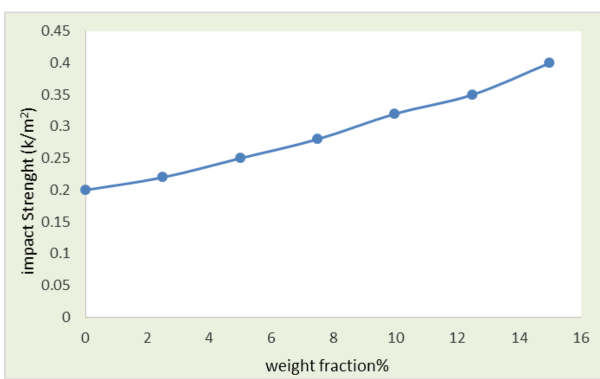

Figure (8) Effect of the gravimetric fraction of walnut shell particles on the values of impact resistance.

5.4 Bending Strength Test:

The bending strength test is one of the complex tests where the sample is subjected to several stresses at the same moment, namely tensile stress at its outer surface and compressive stress at its inner surface, in addition to the shear stress at the interface of this sample. The failure of the composite material occurs under the influence of one of these three stresses depending on the bonding strength Between the base material and the reinforcing material and the strength of the bonding between them [22]. Figure (9) shows the change in the bending strength values with the increase in the weight fraction of walnut husk granules, which shows an increase in these values with an increase in the weighted fracture of walnut husk granules due to their high resistance to compressive stress and shear stress. As mixing walnut shells gives elasticity higher than the values of elasticity coefficients for pure resin, because the stress is distributed on both the resinous materials and the reinforcing material (walnut shell granules). Walnut husk granules with these materials will improve the values of elastic modulus of the resulting materials, as these granules are distributed in a homogeneous manner and extend along the samples and in the transverse direction, thus preventing deformation in the original material.

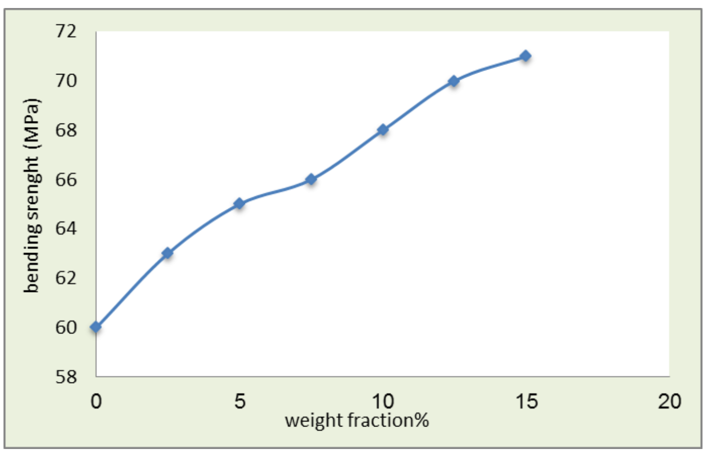

Figure (9): Effect of the gravimetric fraction of walnut husk particles on the bending elasticity values.

6. Thermal Conductivity Test:

The curve of the test results in Figure (10) showed a decrease in the thermal conductivity values of the composite material with an increase in the weight fraction of the walnut husk granules. Heat, the walnut shell granules are a material that is characterized by poor thermal conductivity, and unsaturated polyester resin is a polymeric material with poor thermal conductivity and has a weak thermal conductivity coefficient. All these factors led to a decrease in the thermal conductivity values for all samples [23].

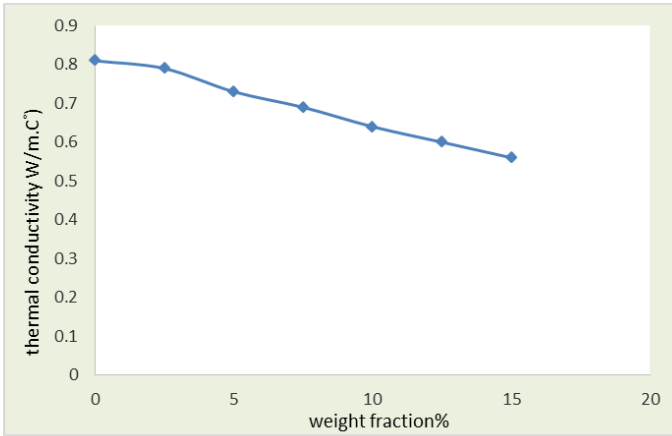

Figure (10) Effect of the weight fraction of walnut shell particles on the thermal conductivity values.

7. Surface morphology:

Electron microscopy shows the conformity of the mechanical behavior and morphology of the fracture surface of the (UPS) samples before mixing and after mixing them with walnut shell granules with a weight fraction (2.5, 5, 7.5, 10, 12.5, 15) % The morphology of any polymeric compound depends mainly on several factors such as Particle size, nature of ingredients, manufacturing conditions and proportions of ingredients as well as product design method [24]. The morphology of the fracture surface of the pure (UPS) samples and the morphology of the fracture surface of the (UPS+WS) samples shown in Figure (11) shows the morphology of the fracture surface of the samples after mixing with different weight fractions of walnut shell granules, and the figures indicate a reasonable and compact distribution of walnut shell particles in Unsaturated polyester and became a part of it mainly. There is a good and uniform dispersion in all samples resulting from a strong interaction and inter-contact between (UPS) and (WS) which resulted in a semi-ducted and smoother fracture surface with an increase in the weight fraction of walnut shell granules and shows a good distribution These granules and the penetration of unsaturated polyester material through them, which means ductile fragility or brittle to turn into semi-ductile.

ISSN: 0011-9342 | Year 2021
Issue: 7 | Pages: 2648- 2663

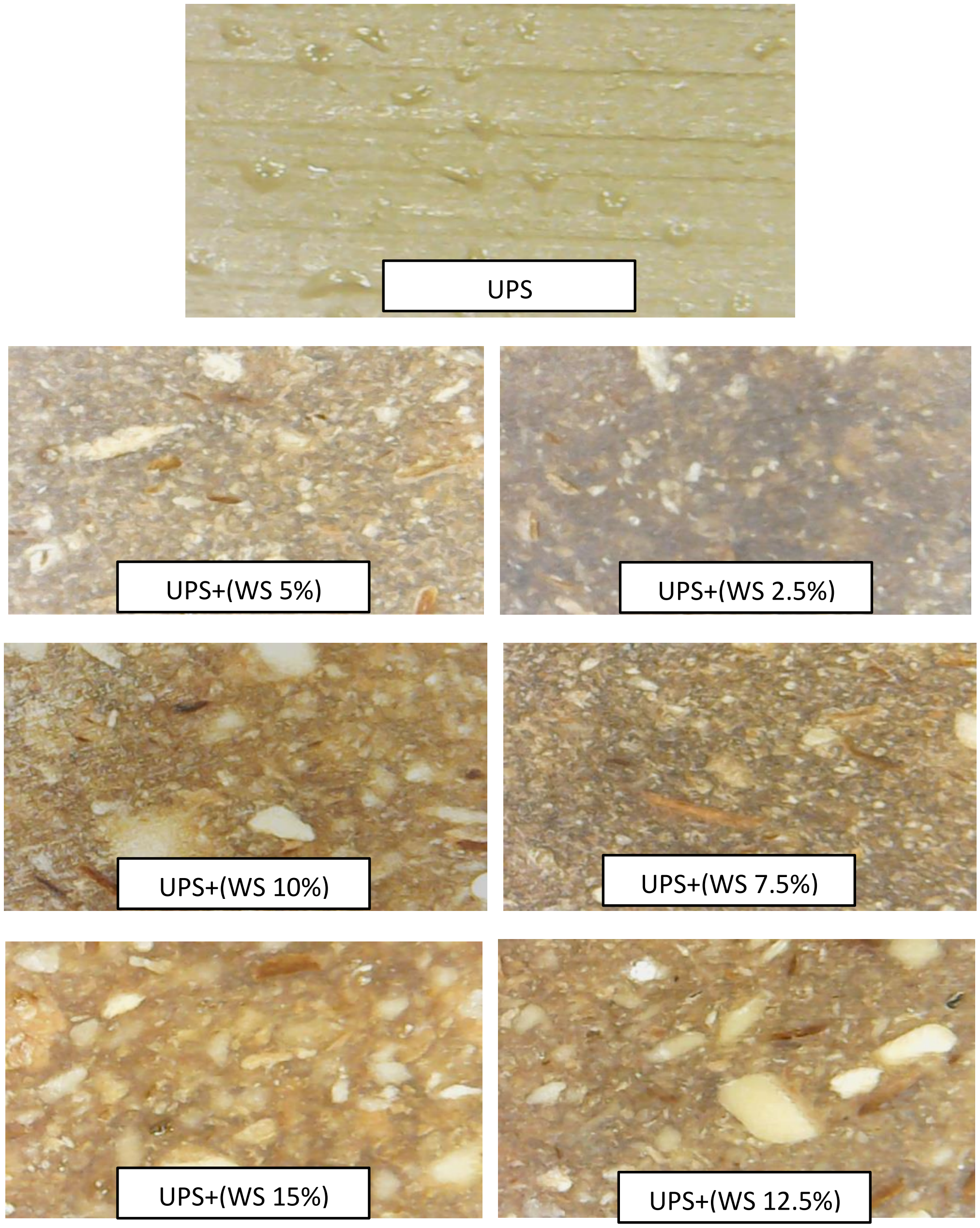

Figure (11) Morphology of the fracture surface of the pure (UPS) and (UPS + WS) samples.

5. Conclusion

The results of the tests showed that the use of walnut granules (WS) in the reinforcement of unsaturated polyester (UPS) leads to:

1- Increasing the mechanical properties (tensile strength, hardness, shock resistance, bending toughness,) of the overlapping material due to the increase in the adhesion force between the walnut shells and the polymer, as well as the low thermal conductivity coefficient of the overlapping. These overlaps are likely to be used as thermal insulating materials.

2- The improvement in the mechanical properties and the decrease in the thermal conductivity confirm the existence of a compatibility between the walnut shells and the polymeric material.

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