

Experimental Investigation of Mechanical Properties of Walnut Shell Particles (WNSP) Reinforced Polyester Composites

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ABSTRACT: Bio-fillers/fibers competes effectively and have increased their demand as compared to synthetic ones due to several advantages like low processing and handling cost, low weight, easily biodegradable, minimum health and environmental hazards, renewable nature etc. However, their poor interfacial adhesion with some matrix material leads to poor/low mechanical properties of the composites. In this study, the mechanical properties of walnut shell particles (WNSP) reinforced polyester composites were studied. The composite specimens were prepared by reinforcing walnut shell powder (having particle size less than 75 microns) in to the polyester matrix. The walnut shell particles of wt. % 0, 10, 20, 30, 40 were taken for the study.

The prepared samples were tested for tensile properties, flexural properties, hardness and impact energy. It was found that the tensile and flexural strength of neat polyester specimen is more than all the composite specimens. The tensile strength increases at 20 wt.% and then decreases with increase in WNSP wt.% whereas the flexural strength greatly fluctuates up to 40 wt.%. The tensile and flexural modulus increases with increase in WNSP content except 30 wt.%. The hardness and the impact energy were found maximum at 40 and 20 wt. % respectively. It has been also observed that the increase in void content percentage decreases and fluctuates most of the mechanical properties. Based on the findings of this work, WNSP works as a great source of natural reinforced composite having large numbers of applications in various industries ranging from defense, space, automotive, sea transport industry and sport materials.

Keywords: *WNSP Reinforced Polyester Composites, tensile strength, flexural modulus, hardness, impact factor.*

INTRODUCTION

The need to focus on natural materials in composite development is necessary as it will save expenditure in importing synthetic materials and at the same time be a source of revenue profit in various industries as natural fiber-reinforced composites material offer high strength to weight ratio, improved dimensional stability, better environmental resistance and degradability, helps in

Waste management and provide employment to rural and small scale industries as compared to conventional composites.

In these days, polymer composite materials are extensively used in engineering applications due to their excellent specific physical and chemical properties. Major research works in composite development have been focused on the use of synthetic resins. Different kinds of resins are epoxide, polyester, vinyl ester and phenol formaldehyde resins [1]. Unsaturated polyester resins are used as the basis of fibre reinforced plastics while glass fibres are the most usual reinforcing materials [2].

Van Suchetclan [3] defined composite as two or more solid phases heterogeneous material which are in intimate contact with each other on a microscopic scale. The matrix, normally a form of resin, keeps the reinforcement in the desired orientation. It protects the reinforcement from chemical and environmental attack, and it bonds the reinforcement so that applied loads can be effectively transferred.

In the course of composite development, the resin (matrix) binds the fibres together, holding them aligned in the important stress directions. Loads applied to the composite are then transferred into the fibres, which constitute the principal load-bearing component, through the matrix, enabling the composite to withstand compression, flexural and shear forces as well as tensile loads [4]. Cellulosic fibers, like walnut shell flour, cashew nut shell, coconut fiber (coir), jute, palm, bamboo, in their natural condition have been used as reinforcement agents of different thermosetting and thermoplastic resins[5,6].

Walnut is an important crop that is cultivated for its edible nuts in temperate regions. Consequently, walnut shells, agriculture by products, are abundant. Normally they are incinerated and dumped without control due to logistic problems such as seasonal production in small scale factories, transport costs and lack of bio-energy plants. [7]. In the present work, walnut shell is used for the composite fabrication with the polyester resin due to their ease of availability, wood like structure and hard in nature and comprises of about 46.6% holocellulose, 25.4 % cellulose, 49.1 % lignin and 3.6 % Ash [8].

S. Nitin [9] studied and used walnut shell particles reinforced polyester composites of wt.% 0 to 40% to improve the mechanical strength and wear properties. The particle size of 1.00 mm was obtained using two sieves 0.5 mm and 1 mm successively. Studies show that the density decreases with increasing percentage of walnut shell particle. Presence of Porosity/voids would be there which decreases the density because there was no pressure applied. All tests are conducted as per ISO in 100 kN servo hydraulic UTM at

different strain rates of 0.01 mm/min. Results shows that ultimate strength is highest for 10% walnut particle of 42.95 M Pa and further drops abruptly at first up to 20% and then drops slowly further to a value of 34.0 MPa. The drop in tensile strength is due to porosity, poor adhesion and poor interfacial interaction between epoxy and shell particles. The drop in modulus of elasticity with increasing percentage of walnut shell particle and is maximum for the value of 932.34 for 10% walnut particle. This was due to increase in % elongation beyond 20%wt reinforcement. Density obtained is very suitable for light weight applications. Tensile strength of 33-41 MPa achieved from these walnut shell particles reinforcement is sufficient for materials replacing wood.

Ahmed J. Mohammed [10] studied mechanical properties of walnuts shells composites. The range of added walnuts shells has the values (0%, 2.5%, 5%, 10%, 15%, 20%, and 25%) of polyethylene weight and, the best fibers ratio was 10 % and 15 %. Obvious improvement in the mechanical parameters was recorded when adding walnuts shells with 10% weight ratio. The properties (LDPE /walnuts shells) composites were analyzed as a function of the powder amount. Walnuts shells are mixed with low density polyethylene and crushed using mixer for 15 minutes at 160 °C and mixing velocity of 50 RPM. The final mold product is introduced in a laboratory compress under 5 tons at 175 °C for 3 minutes in a square frame. The pressure then rises gradually up to 15 tons for 10 minutes and after this period the sample is cooled up to reach room temperature. The elongation of the polymer begins at the percentage (0%) of the polymer pure (109 %) and then decrease when the percentage (2.5%) is (35.5 %) which is a polymer few flexibility and has a hardness high thereby acting shells powder Walnut to fill the spaces between the chains main polymer limited movement of the chains and thus less elongation and then increases until it reaches the maximum value to them when the ratio (10 %) is (44.2 %), and the polymer when this ratio high flexibility and low hardness, and then decrease when the percentage (20%) is (7.8 %) polymeric chains that are not constrained by any be free movement as a result of lack of homogeneity of the mixture, including the nature of the shells powder Walnut characterized by rigidity, which in turn increase the stiffness of the polymer and reduce elongation increased concentration of additive and worked to increase the density of the polymer.

Meysam Zahedi *et al.* [11] studied the characterization of walnut shell/PP composites and compared with wood flour/PP composites. The effects of organo-montmorillonite (OMMT, 0, 3 and 5 wt. %) as reinforcing agent and MAPP as coupling agent (4 and 6 wt. %) on the mechanical and physical properties were also investigated. Composites manufactured via melt compounding and subsequent hot press. The resulting composites had acceptable and comparable properties to wood flour properties and the highest improvement of mechanical properties was achieved at 3% organo-clay loading and 6% MAPP.

Nadir Ayrlimis [12] investigated the walnut shell flour and polypropylene based composites with and maleic anhydride-grafted polypropylene at 40, 50 and 60 weight percentage of the walnut shell for mechanical properties. The bending and tensile modulus of the composites significantly increased with increasing the filler content while the bending and tensile strength significantly decreased. Water absorption and thickness swelling of the composites increased with increasing filler content. The MAPP improved the interfacial adhesion between walnut shell flour and polymer matrix. This research revealed that 40/57/3 formulation of the walnut shell flour/ polypropylene/MAPP can be used in outdoor applications a high dimensional stability.

Method of Composite Fabrication

The fabrication of composite involves the combination of the matrix and fiber or reinforced particles such that the matrix impregnates surrounds and wets the fibers. The process can be adopted on the basis of matrix materials used like thermosetting or thermoplastic materials. They are developed to meet specific design or manufacturing challenges. The important processing methods used for thermosetting polymer are hand layup, bag moulding, process, filament winding, Pultrusion, bulk moulding, sheet moulding, resin transfer moulding, scrap-rotate-scrap mixing. In this present work, **Scrap-rotate-scrap mixing method** is used for the development of WNSP reinforced polyester composites.

Research Gaps

Walnut shells have been used with different polymers like polypropylene, urea formaldehyde and epoxy resins in powder form of coarse size. But no work is found in the combination of walnut shell powder ranging from 200 to 350 meshes and the polyester resin in the available literature.

Objectives

On the basis of available literature and research gaps, the following objectives are proposed for the present work.

To prepare walnut shell powder from walnut shells of size less than 75 microns, to develop the walnut shell particles (WNSP) reinforced polyester composites with different wt. % (0, 10, 20, 30, and 40) of WNS powder and to investigate the mechanical properties of prepared composites and compare with neat polymer specimen.

FABRICATION AND EXPERIMENTATION

MATERIALS

1. Matrix

The unsaturated polyester resin was taken from the Revex Plasticizers (Pvt.) Ltd., Faridabad India. The resin has 1280 kg/m³ density with 32% monomer content [13]. The catalyst methyl ethyl ketone peroxide (MEKP) used for the curing of matrix material were also taken from the same firm. Unsaturated polyester is a solid in polymerizable monomer. It is formed by condensation reaction between a glycol and an unsaturated dibasic acid.

2. Releasing Agent

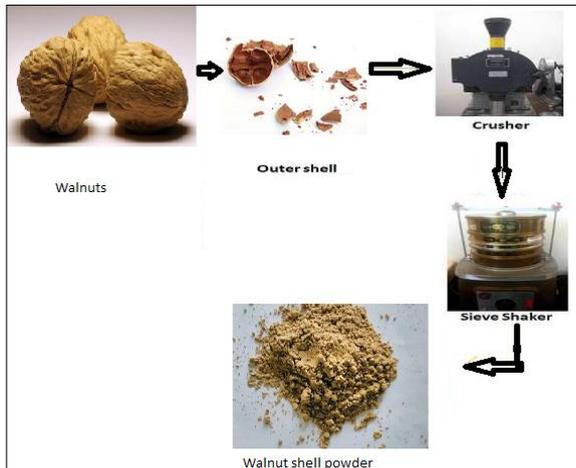
Polyvinyl alcohol was used as the releasing agent for the preparation of composites. It is soluble in water and forms glue like paste when mixed in standard vol. fraction of both hot water and polyvinyl alcohol.

3. Extraction of Walnut Shell Particles

The walnuts shells were purchased from the local market and crushed into a crusher, then milled into a disc mill. The powder received from the disc mill was sieved using sieves of size 75 microns to 250 microns. The powder passed from 75 microns was taken for composites. Fig.1 shows the process of preparation of walnut shell powder.

METHOD OF COMPOSITE PREPARATION

Firstly, the required amount of polyester resin was mixed with catalyst MEKP of wt. % 1.5 of resin. Then the walnut shell powder in the proportionate amount of resin was mixed with prepared resin mixture for 2 minutes using scrap-rotate-scrap method. A mould of glass was prepared of size 21×40×20 mm for pouring of the mixture so that the desire shape of composites can be obtained after solidification. The similar procedure was applied for preparation of the rest of the composites with different wt. % of WNSP. Table 1: shows the composition of composite specimens to be prepared.



Composites Specimen	Wt.% of WNS powder	Wt.% of polyester Resin	Wt.% of accelerator and catalyst
1	0	100	1.5 % of polyester resin
2	10	90	
3	20	80	
4	30	70	
5	40	60	

Figure1: Preparation of walnut shell powder

Table 1: Composition of composite specimens

The catalyzed polyester WNSP mixture was then poured slowly into the tray at a distance of 30 cm. An extremely thin stream of mixture was poured into the tray to reduced trapping of air bubbles. The mixture was left untouched for 10 min to allow air bubbles to rise to the surface and pop-stick was used to “pop” the bubbles. A glass top plate was placed over the semi solid liquid mixture and left for 24 h for curing. The composite was then post-cured for 2 h at 80° c before removing from the mold. The reinforcement of composites becomes limited up to 40 wt. % of WNSP because of inappropriate mixing. Figure: 2 shows the step by step procedure for the preparation of composites.

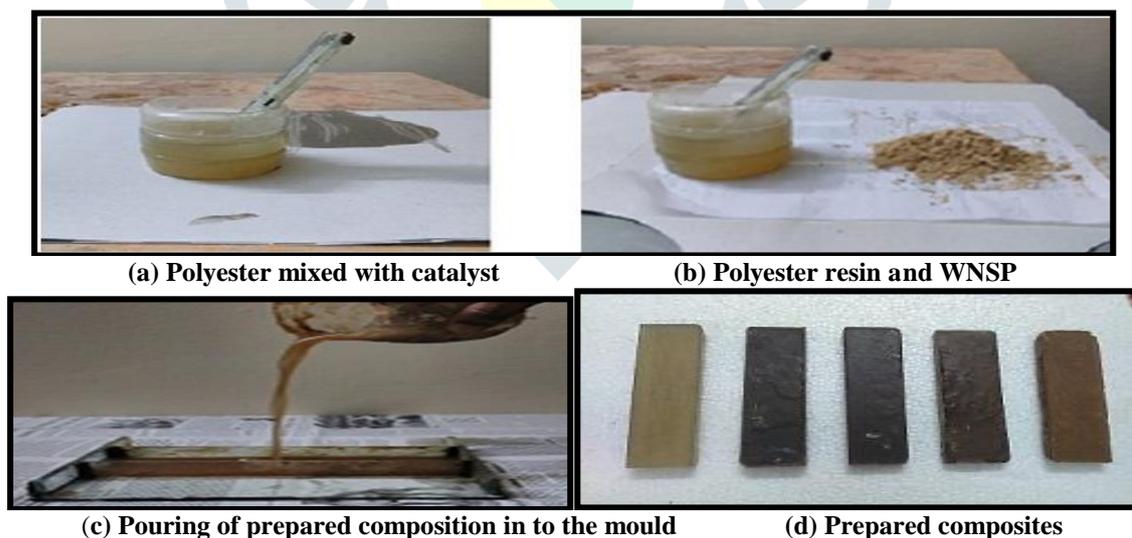
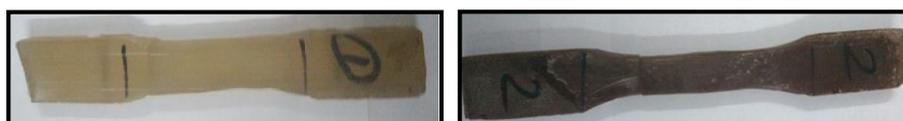


Figure 2: (a)-(d) Procedure of composites preparation

The developed composites were the prepared into the standard size and shape by cutting in order to test the specimens for the evaluation of their mechanical properties. Figure 3: (a)-(e) shows dumble shape specimens for tensile testing and figure 4: (a)-(e) shows rectangular shape specimens for flexural testing.



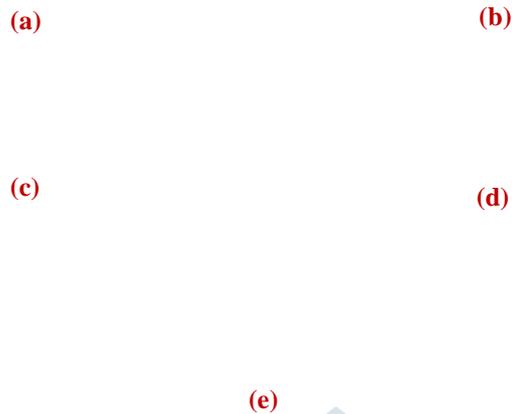


Figure 3: (a)-(e) Dumbbell shape specimens for tensile testing

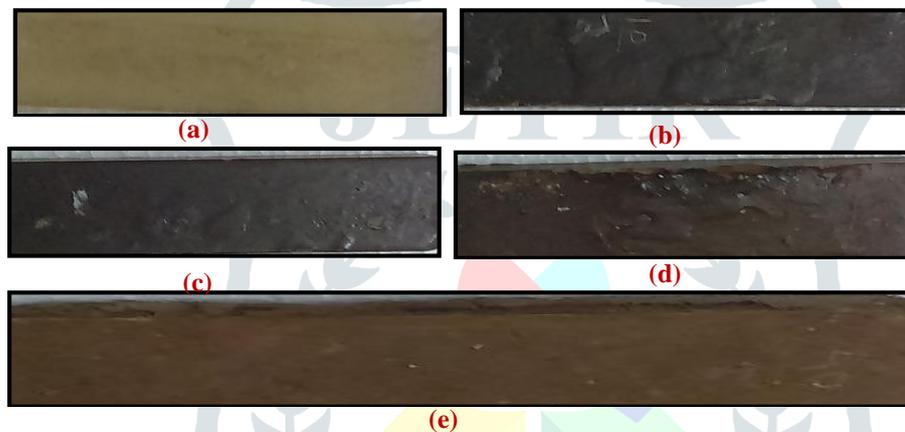


Figure 4: (a)-(e) Rectangular shape specimens for flexural testing

TESTING OF MECHANICAL PROPERTIES

The prepared samples were tested for tensile, flexural, hardness and impact properties. The tests were performed in the mechanical testing department of Chandigarh Industrial and Tourism Development Corporation Limited (CITCO), Chandigarh.

1. Tensile Testing

The tensile testing was performed on FIE make Universal Testing Machine (UTM) of capacity 1000 KN, resolution 0.05 KN at room temperature 25°C and relative humidity 40 – 60 %. A standard test method IS 1608:2005 was used for the testing. The results were obtained in terms of tensile strength and load versus displacement curves. Figure 5: shows the view of UTM at CITCO.



Figure 5: Universal Testing Machine



Figure 6: Flexural test setup

2. Three Point Flexural Test

Three point bending tests of specimen were carried out on the same machine i.e. UTM. All the tests were performed according to ASTM-D 790-02 standards [14] at a normal cross head speed of 1 mm/min. The results were obtained in terms of flexural strength and load values with respect to displacement. The loading direction was in transverse direction for all three point bending tests of samples. Figure 6: shows the test setup for flexural testing.

3. Rockwell Hardness Tester

A Rockwell hardness testing machine of (FIE) make was used to test the specimen for hardness as per test standards IS 1586-2000. The measured hardness was obtained in HRL. The Rockwell test determines the hardness by measuring the depth of

penetration of an indenter under a large load compared to the penetration made by a preload. There are different scales, which are denoted by a single letter, that use different loads or indenters.

The determination of the Rockwell hardness of a material involves the application of a minor load followed by a major load, and then noting the depth of penetration, hardness value directly from a dial, in which a harder material gives a higher number. The chief advantage of Rockwell hardness is its ability to display hardness values directly, thus obviating tedious calculations involved in other hardness measurement techniques. Figure7: shows an image of Rockwell Hardness testing machine.



Fig. 7: Rockwell Hardness Testing Machine

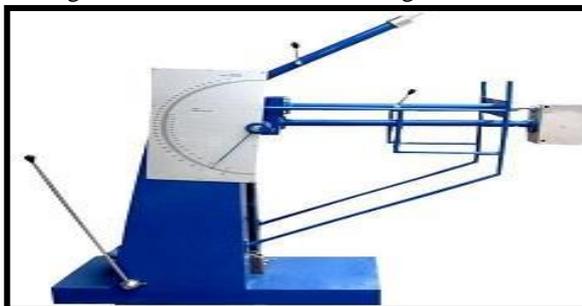


Fig. 8: Izod impact test machine

4. Impact test

The term brittle fracture is used to describe rapid propagation of cracks without any excessive plastic deformation at a stress level below the yield stress of the material. Metals that show ductile behavior usually can, under certain circumstances, behave in a brittle fashion. The stress needed to cause yield rises as the temperature falls. At very low temperatures, fracture occurs before yielding. Impact tests are used not also to measure the energy absorbing capacity of the material subjected to sudden loading; but also to determine the transition temperature from ductile to brittle behavior.

5. Izod Impact Test

An Izod impact testing machine, FIE make of range 1 to 175 J was used for finding the impact energy absorbed by the specimen. The tests were prepared as per ASTM-D 756 standards [15]. The test piece is a cantilever, clamped upright in an anvil, with a V notch at the level of the top of the clamp. The test piece is hit by a striker carried on a pendulum which is allowed to fall freely from a fixed height, to give a blow of 120 ft lb energy. After fracturing the test piece, the height to which the pendulum rises is recorded by a slave friction pointer mounted on the dial, from which the absorbed energy amount is read.

RESULTS AND DISCUSSION

DENSITY MEASUREMENT OF WNSP

The WNSP of size less than 75 microns was taken for composites preparation. The actual density of the powder was calculated using water immersion method as shown in figure 9. Five ml of water was taken into a measuring tube and one gram of WNSP was poured into the water. The volume displaced by one gram of powder was observed as 0.55 ml and taken for density measurement. The density by this method can be expressed in terms of gm/ml or gm/cc.

$$\text{Density } (\rho) \text{ of WNSP} = \frac{\text{Mass of WNSP taken}}{\text{Volume of water displaced}} = 1/0.55 = 1.82 \text{ gm/ml}$$

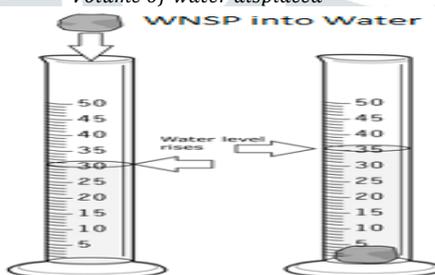


Figure 9: Water immersion method [15]

The density of prepared composites, given in table: 2, is calculated by the same method. The density of WNS composite specimen with 10 wt.% has a density of 1247 kg/m³ which is found to be less than that of the neat polyester specimen. The increase in wt.% of WNSP increases the density of the composite and found maximum density at 40 wt%.

Table 2: Measured composite's density

Sr. No.	WNSP wt. %	Density (kg/m ³)
1	0	1280
2	10	1247
3	20	1260
4	30	1285
5	40	1334

This is due to the fact that the WNSP has more density than the polyester resin and increasing in WNSP content increases the composite density.

VOID CONTENTS

The void contents provide estimation of the quality of the composites. The theoretical and actual densities of composites may not always be in the better agreement. It happens when voids are present in the composites [16]. The volume fraction of void content may be calculated by the following relationship:

$$V_v = 1 - (\rho_{ce} / \rho_{ct}) \tag{1}$$

Where, ρ_{ce} = Experimental density (gm/cm³),

ρ_{ct} = Theoretical density (gm/cm³)

The void content increases up to 8.50 % with increase in the wt. % of WNSP from 0 to 30. This is an indication of poor quality of composites. Increasing void contents may increase variation and scatter in the strength properties. Table 3 shows the void contents percentage of all the composite specimens and figure: 10 shows its variation with respect to the WNSP wt.%.

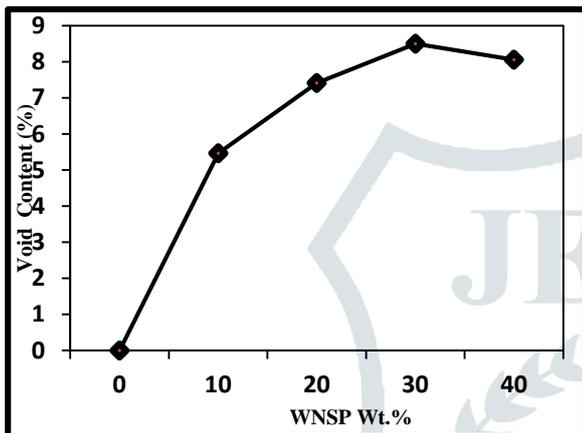


Fig. 10: Variation in void contents with WNSP wt.%

WNSP wt.%	Experimental density ' ρ_{ce} ' (g/cm ³)	Theoretical density ' ρ_{ct} ' (g/cm ³)	Void content (%)
0	1.280	1.280	0
10	1.247	1.319	5.46
20	1.260	1.360	7.41
30	1.285	1.405	8.50
40	1.334	1.451	8.06

Table 3: Measured densities and void content

TENSILE PROPERTIES

Figure: 11-15 shows the load versus displacement curve of 0, 10, 20, 30, 40 wt.% WNSP composites recorded in the universal testing machine (UTM) as per ASDM standards [17]. Fig 5.3 illustrates that there is no yielding in the specimen due to its brittleness. The load carrying capacity and percentage elongation of neat polyester specimen is found to be maximum i.e. 4875 N and 9% respectively. The increase in wt.% of WNSP decreases the percentage elongation and increases the brittleness of the composites. It is observed due to decreases in the bonding strength of WNSP with polyester resin.

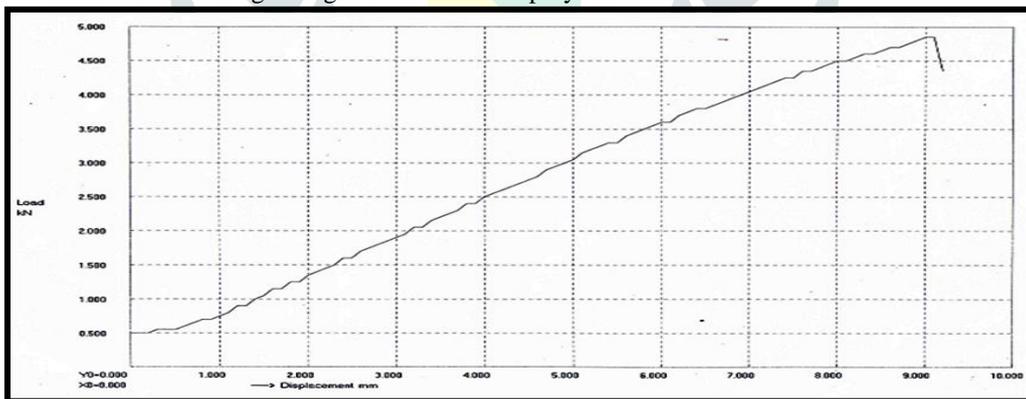


Figure 11: Load versus displacement curve of neat polyester

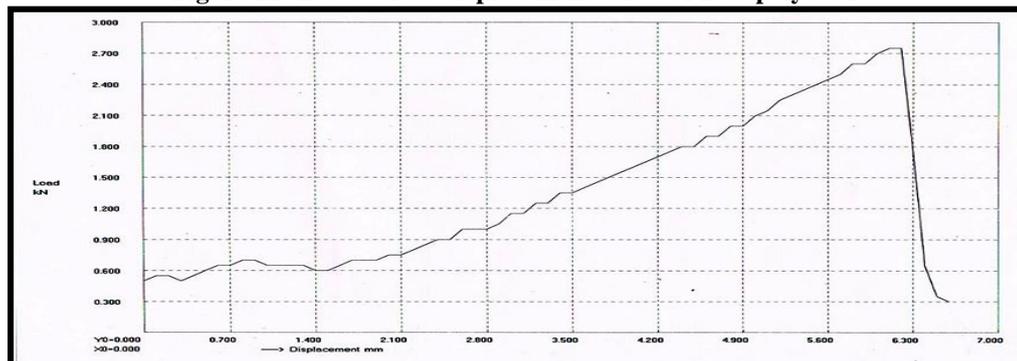


Figure 12: Load versus displacement curve of 10 wt.% WNSP composites

It is also seen that the maximum load values are varying from sample 1 to sample 5. It is attributed due to the fact that the void content percentage increases with increase in WNSP wt.% which results in degradation in the quality of composites. The cross-sectional area of composites also varies from sample 1 to 5 which results in the variation of the load carrying capacity.



Figure 13: Load versus displacement curve of 20 wt.% WNSP composites

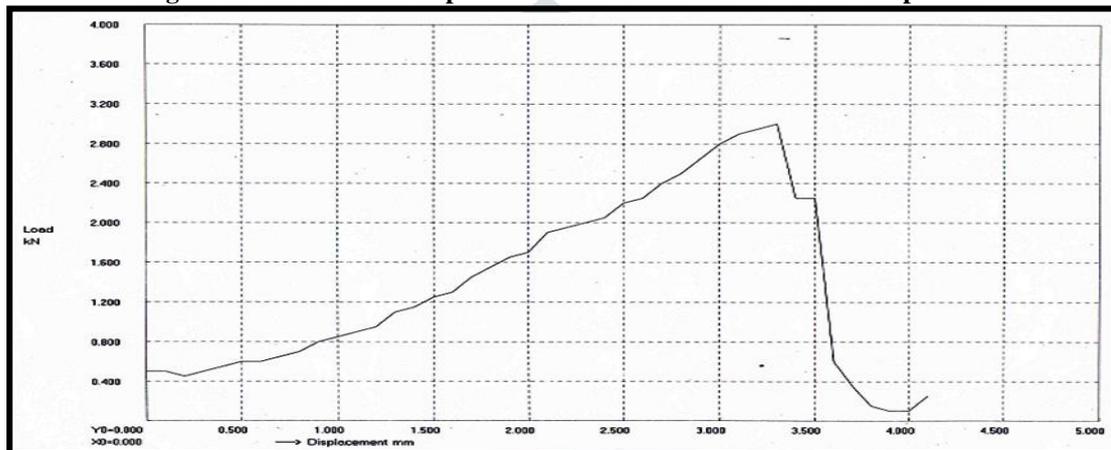


Figure 14: Load versus displacement curve of 30 wt.% WNSP composites

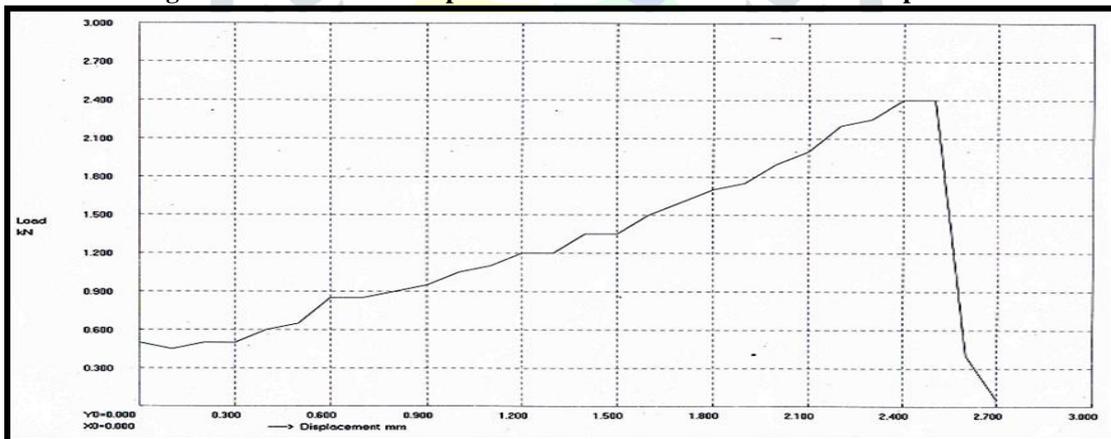


Figure 15: Load versus displacement curve of 40 wt.% WNSP composites

The ultimate tensile strength of composite specimens is directly obtained from the UTM and other terms like specific tensile strength, tensile modulus, specific tensile modulus and percentage elongation are calculated using the following relationships.

$$\text{Tensile modulus, } E \text{ (MPa)} = \frac{\text{Stress}}{\text{Strain}} \tag{2}$$

$$\text{Where, Stress, } \sigma \text{ (MPa)} = \frac{\text{Maximum force(N)}}{\text{Cross-sectional Area (mm}^2\text{)}} \tag{3}$$

$$\text{and Strain, } \epsilon = \frac{\text{change in length, } \Delta l \text{ in mm}}{\text{original length, } l \text{ in mm}} \tag{4}$$

$$\text{Percentage elongation, } e \text{ (\%)} = \frac{\text{change in length, } \Delta l \text{ in mm}}{\text{original length, } l \text{ in mm}} \times 100 \tag{5}$$

$$\text{Specific tensile strength, } \sigma_{sp} \text{ (MPa/kgm}^{-3}\text{)} = \frac{\text{Ultimate tensile strength(MPa)}}{\text{Density } (\frac{\text{Kg}}{\text{m}^3})} \tag{6}$$

$$\text{Specific tensile modulus, } E_{sp} \text{ (MPa/kgm}^{-3}\text{)} = \frac{\text{Tensile Modulus (MPa)}}{\text{Density } (\frac{\text{Kg}}{\text{m}^3})} \tag{7}$$

Figure 16 shows the variation in ultimate tensile strength and modulus with WNSP wt.%. It is observed that the increase in wt.% decreases the tensile strength due to increase in brittleness. Improper mixing and agglomeration of walnut shell particles may be the reason of decreasing trend of tensile strength. The particles agglomeration decreases the bonding strength between particles and resins which results in decrease in the tensile strength. The tensile modulus increases up to 20 wt.%, slightly decreases at 30 wt.% and attain a maximum value at 40 wt.%. The tensile modulus of all composite specimens is observed greater than that of the neat polyester. This is an indication of increase of stiffness and decrease of deformation. Table 4 shows the tensile properties of the composite specimen at different WNSP wt.%.

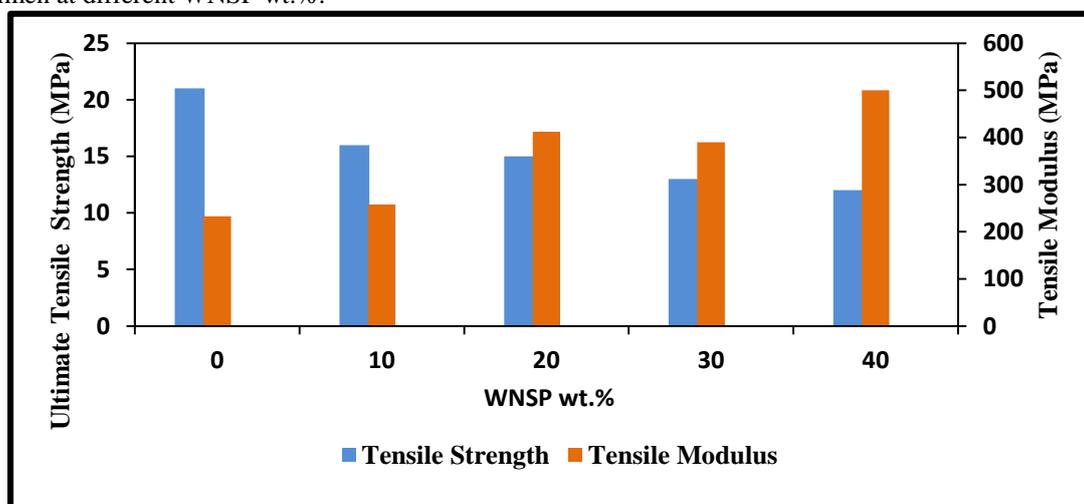


Figure 16: Variation in ultimate tensile strength and modulus with WNSP wt.%

Table 4: Tensile properties of composite specimens

Wt.% of WNSP	Max. Force(N)	Ultimate tensile strength, (MPa)	Specific tensile strength, MPa/kgm ⁻³	Tensile modulus (MPa)	Specific tensile modulus, MPa/kgm ⁻³	Percentage Elongation
0	4857	21	0.0164	233	0.182	9
10	2750	16	0.01283	258	0.2026	7.23
20	2300	15	0.0119	412	0.327	4.22
30	3000	13	0.010116	390	0.3035	3.8
40	2400	12	0.009	500	0.3750	2.74

FLEXURAL PROPERTIES

The prepared composites are tested for flexural properties as per ASTM-D-790-02 standard on UTM and the load values are recorded directly from machine [14]. The flexural properties like flexural strength, deflection, flexural modulus, specific flexural strength and modulus are calculated from the following relationships:

$$\text{Flexural strength, } \sigma_f \text{ (MPa)} = \frac{3FL}{2bt^3} \tag{8}$$

$$\text{Deflection, } d \text{ (mm)} = \frac{FL^3}{48E_f I} \tag{9}$$

$$\text{Flexural modulus, } E_f \text{ (MPa)} = \frac{FL^3}{4bd t^3} \tag{10}$$

$$\text{Specific flexural strength, } \sigma_{fsp} \text{ (MPa/kgm}^{-3}\text{)} = \frac{\text{Ultimate flexural strength (MPa)}}{\text{Density } (\frac{\text{kg}}{\text{m}^3})} \tag{11}$$

$$\text{Specific flexural modulus, } E_{fsp} \text{ (MPa/Kgm}^{-3}\text{)} = \frac{\text{Flexural Modulus (MPa)}}{\text{Density } (\frac{\text{kg}}{\text{m}^3})} \tag{12}$$

Where, F- Force (N),

L- Length between two point, (mm),

b- Width of samples, (mm),

d- Deflection, (mm),

t- Thickness, (mm).

The calculated flexural properties are shown in table 5.

Table 5: Flexural properties of composite specimens

Wt.% of WNSP	Max. force(N)	Max. deflection (mm)	Ultimate flexural strength (MPa)	Specific flexural strength (MPa/kgm ⁻³)	Flexural modulus (MPa)	Specific flexural modulus (MPa/kgm ⁻³)
0	873	4.4	24.20	0.0189	233.4	0.1824
10	745.6	2.4	17	0.01364	257.4	0.2065
20	549.5	2.723	19.40	0.0154	412	0.327
30	745.56	1.85	16.30	0.01288	386.44	0.3007
40	667	1.45	17.10	0.01350	500	0.3947

Figure: 17 shows the variation in flexural strength and modulus with WNSP wt.%. It is clearly seen that the neat polyester shows maximum flexural strength as compared to the WNSP composites. The flexural strength of WNSP composites does not follow an increasing or decreasing trend. But it shows fluctuation with increase in WNSP wt.%. It is attributable due to increase in void percentage of the composites. The flexural modulus increases up to 20 wt.% then slightly decreases at 30 wt.% . It attains maximum value at 40 wt.% of WNSP. The specific flexural strength and modulus almost follow the similar trend as followed by the flexural strength and modulus.

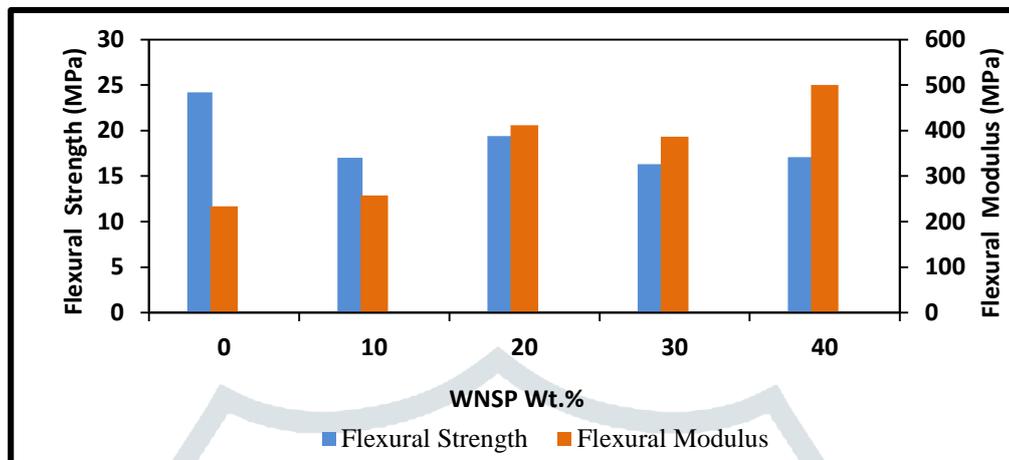


Figure 17: Variation in flexural strength and modulus with WNSP wt.%

HARDNESS TESTING

The prepared composites are tested as per IS 1586-2000 standard on Rockwell hardness tester. The hardness of composites significantly increase with increase in WNSP particle content up to 40 wt.% except 30 wt.%. The hardness values of sample 2 and sample 4 are found to be 54 HRL. The hardness of composite with 40wt.% is 16% higher than that of the neat polyester. Table 6: Shows the values of hardness at different wt.% of WNSP Composites.

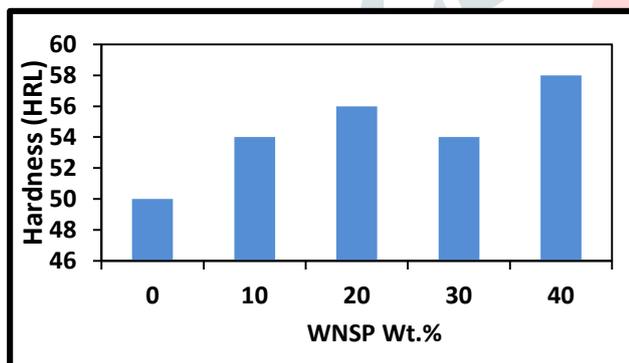


Figure 18: Variation in hardness with WNSP wt.%

Specimens	WNSP wt.%	Rockwell Hardness (HRL)
1	0	50
2	10	54
3	20	56
4	30	54
5	40	58

Table 6 Hardness at diff. wt.% of WNSP composites

IMPACT TESTING

An Izod impact testing machine of (FIE) make was used to test the samples as per ASTM-D-256 [15]. A V-notch is provided in the specimen to initiate the test. The impact energy of the specimens increases with increase the WNSP loading up to 20 wt.% where as it remains constant for 30 and 40 wt.% composites. The 20 wt.% specimen has high impact energy as compare to others. Table: 7 shows the impact energy values of specimens at different WNSP wt.%.

Specimens	WNSP wt.%	Impact energy (Joules)
1	0	1.5
2	10	2
3	20	2.5
4	30	2
5	40	2

Table: 7 Impact energy of specimens at different WNSP wt.%

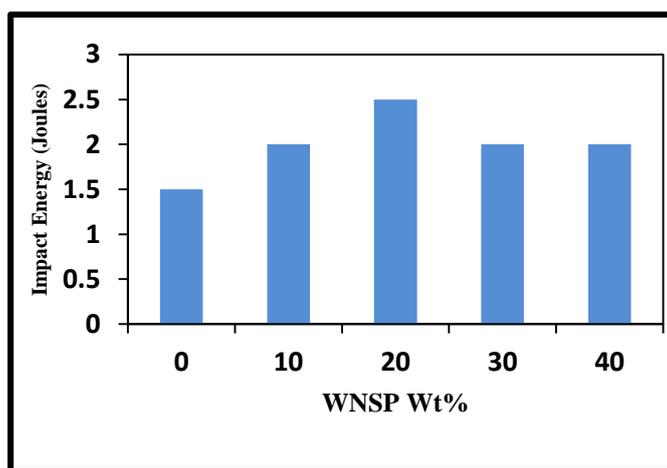


Figure 19: Variation in impact energy with WNSP wt.%

CONCLUSIONS

The walnut shell powder of size < 75 microns was used for composite preparation and testing of mechanical properties. On the basis of experiments performed, the following conclusions can be drawn. The percentage of void content increases with increase in the WNSP up to 30 wt.% and decreases from 30 to 40 wt.%. Increase in void content indicates the bad quality of composites and variation in mechanical properties. The increase in wt. % of WNSP decreases the tensile strength of composites. The neat polyester specimen has maximum strength as compared to the composite specimens. The tensile modulus of composite specimen at 40 wt. % of WNSP is found to be 2.14 times greater than the neat polyester. The flexural strength of the composite specimens fluctuates as the WNSP wt.% increases. The composites hardness increases with increase in wt. % of WNSP from 0 to 40 except 30 wt.%. It is found 50 HRL for neat specimen and 58 HRL for 40 wt. % specimen. The impact energy of all the composite specimens is found maximum than the neat polyester specimen.

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