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Mechanical Properties of Tere-Phthalic Unsaturated Polyester Resin Reinforced With Varying Weight Fractions of Particulate Snail Shell

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Abstract: *The objective of this work is to investigate the mechanical properties of particulate snail shell reinforced unsaturated polyester composite. 5wt% ground snail shell of particle size 625microns was introduced to unsaturated polyester matrix to produce a composite. Other specimens were produced at 10, 15, 20, 25 and 30 weight percentages of the particulate filler in unsaturated polyester matrix. Mechanical tests were conducted on prepared samples of the composite material. The results showed that the flexural strength of the composite with 20wt% snail shell particulate reinforcement was greatly enhanced and the impact and hardness properties were greatly improved at 5wt% filler loading. The composite could be considered for applications in areas where high impact strength is a requirement such as in shipping containers. The 20wt% snail shell reinforced unsaturated polyester can be used in place of pure polyester for applications where flexibility is of utmost importance.*

Keywords: *Snail Shell, Unsaturated Polyester, Composite, Mechanical Properties, filler*

I. Introduction

The use of polymer matrix composite has found wide application in our modern day world. This is as a result of the combination of properties which these materials possess. Some of the properties of polymer matrix composites include These include specific strength, high modulus, good fracture and fatigue properties as well as corrosion resistance (Agunsoye et.al. 2013). One of the factors which make plastics attractive for engineering application is the possibility of property enhancement through fibre reinforcement (Crawford, 1998). The major thermosetting resins used in conjunction with glass fibre reinforcement are unsaturated polyester resins and to a less extent epoxy resins. These materials offer most important advantages such as their inability to liberate volatiles during cross-linking and their ability to be moulded using low pressures at room temperature (Crawford, 1998). Natural filler-reinforced polymers provide increase in the degradability capability of the resulting product (Fakhrul and Isram, 2013). Fibres like oil palm empty fruit bunch, Kola nitida wood fibre, as well as several fillers such as rice husk have been used as reinforcing agents of different thermoplastic and thermosetting plastic resins (Ahmad, et.al. 2012; Obidiegwu and Ogbobe, 2012; Tran, et.al. 2013). There is an overwhelming interest in filler and natural fibre reinforced polymers owing to their ease of processing and low cost as some of these fillers are regarded as waste. In the development of polyester/eggshell particulate composites, the density and hardness values of the polyester/eggshell particulate composites increased steadily with increasing eggshell addition, compressive strength, flexural strength and impact energy increased (Hassan, et.al. 2012). An investigation into the fibreglass waste/polyester resin composites showed the impact strength to be excellent (Araujo, et.al. 2006). The study of some tensile properties of unsaturated polyester resin reinforced with varying volume fractions of carbon black nanoparticles revealed that tensile strength, percentage elongation and tensile toughness at fracture increased as the volume fractions of carbon black nanoparticles increased from 1% to 5% (Obayi, et.al. 2008). The effect of untreated and treated coconut shell reinforced unsaturated polyester composites were studied, it was observed that the mechanical and thermal properties of unsaturated polyester/coconut shell composites were enhanced (Salmah, et.al. 2013). In the study of the effect of kaolin powder reinforced unsaturated polyester composite, results showed that the addition of kaolin resulted to improved compression strength, flexural modulus, flexural strength, impact strength and also the hardness of unsaturated polyester (Al-asade, et.al. 2008). In the study of the tensile behaviour and hardness of coconut fibre-ortho unsaturated polyester composites, the results showed that the tensile properties at 10% fibre load were greatly enhanced (Onuegbu, et.al. 2013). Their versatility in use allows unsaturated polyester resins to be used in a host of composite applications. Composite parts can be made at temperatures as low as 15°C to as high as 150°C depending on the processing requirement of the application (www.ncsresins.com). Unsaturated polyester resins also have excellent service temperatures. They have good freeze-thaw resistance and can be designed for use in many low to moderate temperature applications ranging from refrigerated enclosures to hot water geysers (www.ncsresins.com). This research work focuses on the determination of the effect of snail shell filler loading on the mechanical properties of unsaturated polyester.

II. Materials And Methods

2.1. Materials:

Snail shells were obtained from Akoka market in Lagos. Unsaturated Polyester resin (matrix), Methyl Ethyl Ketone Peroxide (catalyst) and Cobalt Naphthanate (accelerator) were bought from Ojota Chemical Market, Lagos.

2.2. Samples Preparation:

2.2.1. Preparation of snail shell filler

The snail shells were thoroughly cleaned to remove dirt and were dried in the sun for three days. After drying, the shells were ground and then sieved with a hand sieve size of 625 microns in the Metallurgical and Materials Engineering Laboratory of the University of Lagos.

2.2.2. Preparation of unsaturated polyester composite:

The required materials were weighed out using an electronic weighing balance. The weight percentages of the constituents are shown in table 1. In synthesizing the reinforced polyester composites, the mass of the polyester was varied with that of the reinforcement to give a total of 100grams. The filler is added into the polyester resin and stirred continuously with a glass rod for about two minutes until a uniform mixture was observed. Thereafter, 1g of catalyst was added with the help of disposable syringe and stirred for about two minutes, after which 0.5g of accelerator was also added and stirred for about two minutes. The mixture was poured into a mould already coated with paper tape as a mould release agent and allowed to cure for two hours. This procedure was repeated for other specimen as shown in table 1 with changes in the weight percentages of the particulate filler. A control sample was produced without the addition the particulate snail shell filler. After curing, the samples were removed from the mould.

Table 1. Formulation of filler/polyester composite

Specimen	Composition (g)			
	Particulate snail shell filler	Tere-phtallic unsaturated polyester	Methyl ethyl ketone peroxide (catalyst)	Cobalt naphthanate (accelerator)
A	5.0	95.0	1.0	0.5
B	10.0	90.0	1.0	0.5
C	15.0	85.0	1.0	0.5
D	20.0	80.0	1.0	0.5
E	25.0	75.0	1.0	0.5
F	30.0	70.0	1.0	0.5
Control	0.0	100.0	1.0	0.5

Figure1. Snail shells

Figure2. Particulate snail shell filler

Figure3. The unsaturated polyester, accelerator and catalyst used.

Figure4. Cast samples of unsaturated polyester/particulate snail shell composite.

2.3. Mechanical Test on the Specimens

2.3.1. Tensile test Instron Universal Testing Machine operated at a cross head speed of 10mm/min was used for the tensile testing of the samples. The tensile test specimen preparation and testing procedures were conducted in accordance with the American Society of Testing and Materials D412 (ASTM D412).

2.3.2. Flexural test

Three points flexural testing was conducted using Testometric Testing Machine with serial number 25257 and capacity M500-25KN at Federal Institute of Industrial Research, Oshodi (FIIRO) in Lagos. The flexural test was carried according to ASTM D7264 at a cross-head speed of 20mm/min, maintaining a span of 100mm. This test was conducted at room temperature. The flexural test specimens were of 120 X 50 X 10 mm.

2.3.3. Hardness test

The hardness test was carried out at Obafemi Awolowo University, Ife. The hardness of a polymeric material is a complex property related to mechanical property such as modulus, strength, elasticity and plasticity. This relationship to mechanical properties is not usually straight forward, though there is a tendency for high modulus and strength values to correlate with higher degrees of hardness within classes of materials. The hardness test was carried out on the polymeric material composite at different filler content at 0, 5, 10, 15, 20, 25 and 30 wt% of filler content.

2.3.4. Impact test

This test was also carried out at Obafemi Awolowo University, Ife. Impact test is a standard method of determining the impact resistance of materials. An arm held at a specific height (constant potential energy) is released. The arm hits the sample and breaks it. From the energy absorbed by the sample, its impact energy is determined. A notched sample is generally used to determine impact energy and notch sensitivity. Impact test are used in studying the toughness of a material. A material's toughness is a factor of its ability to absorb energy during plastic deformation.

III. Results And Discussions

The results of the mechanical test are shown in table 2.

Table 2: Result of mechanical tests on the samples with varying percentages of snail shell reinforcement

Snail shell reinforcement (%)	Bending strength at peak/break (MPa)	Deformation at peak (mm)	Impact strength (Joules)	Brinell hardness (BHN)	Ultimate tensile strength (MPa)	Tensile Strain (mm/mm)
0	30.85	5.170	3.81	24.87	12.0539	0.0395
5	40.48	3.0520	5.13	31.20	5.7765	0.0342
10	31.54	2.8280	3.10	29.47	4.4247	0.0261
15	20.43	3.8250	4.20	24.20	7.2458	0.0178
20	46.24	3.0320	4.80	21.06	5.4060	0.0161
25	35.43	2.7780	4.24	20.52	5.4324	0.0153
30	30.21	2.5880	3.60	20.10	8.2354	0.0322

3.1. Bending Strength:

From figure 4 below, the snail shell reinforced polyester composite had its maximum bending strength at peak at 20wt% filler concentration after which it continually dropped because the increase in weight percent of filler reduced the deformability of the matrix, and in turn reduced the ductility of the composite. The reduction in the bending strength at peak of the snail shell reinforcements could be attributed to controlled mobility of matrix by filler particles. As the amount of reinforcement increases, there is reduction in total surface area available for matrix-filler interaction.

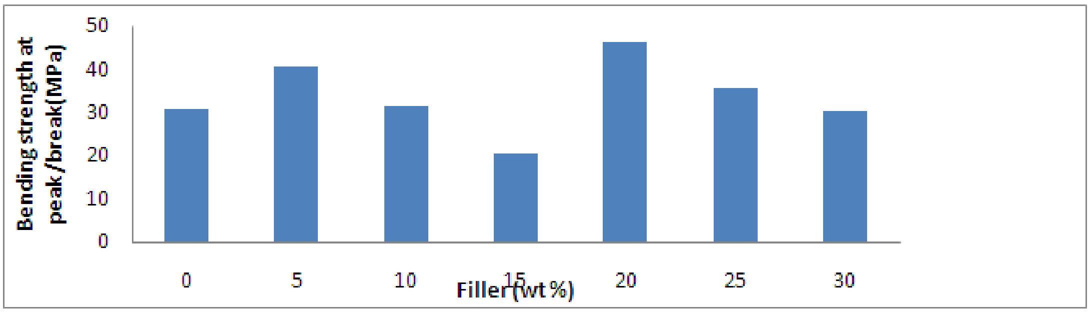

Figure4. Chart of bending strength against filler concentration

3.2. Deformation at peak

Figure 5 shows the deformation at peak of the reinforcement showing an undulating/sinusoidal pattern. The addition of snail shell particulate reinforcement to the unsaturated polyester matrix decreased the deformation of the when load was applied

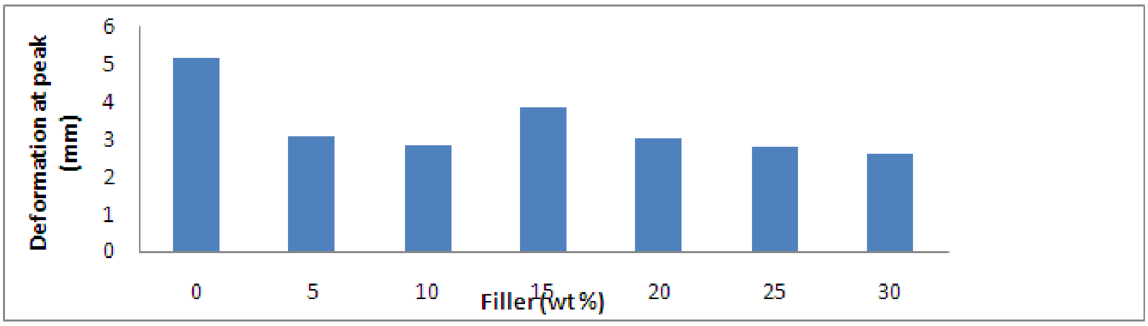

Figure5. Chart of deformation at peak against filler concentration

3.3. Impact Strength

Figure 6 below shows the amount of energy the samples can absorb prior to fracture. It was observed that the particulate snail shell reinforced composite absorbs maximum energy at 5%. The impact strength decreases as the filler content increases. This is mainly due to the reduction of elasticity of the material due to filler addition and thereby reducing the deformability of matrix. An increase in concentration of filler reduces the ability of matrix to absorb energy and thereby reducing the toughness, so impact strength decreases.

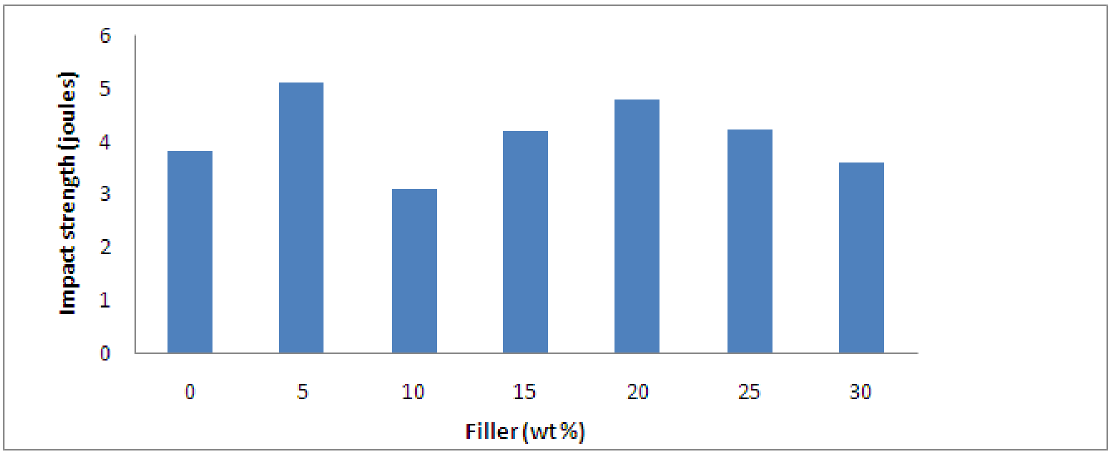

Figure6. Chart of impact strength against filler concentration

3.4. Hardness

From figure 7 below, the highest level of hardness of the composite as a result of the particulate snail shell reinforcement addition was at 5%. The irregular/unpredictable pattern of the hardness may be attributed to the poor interfacial bonding or surface adhesion of the fillers and polyester resin.

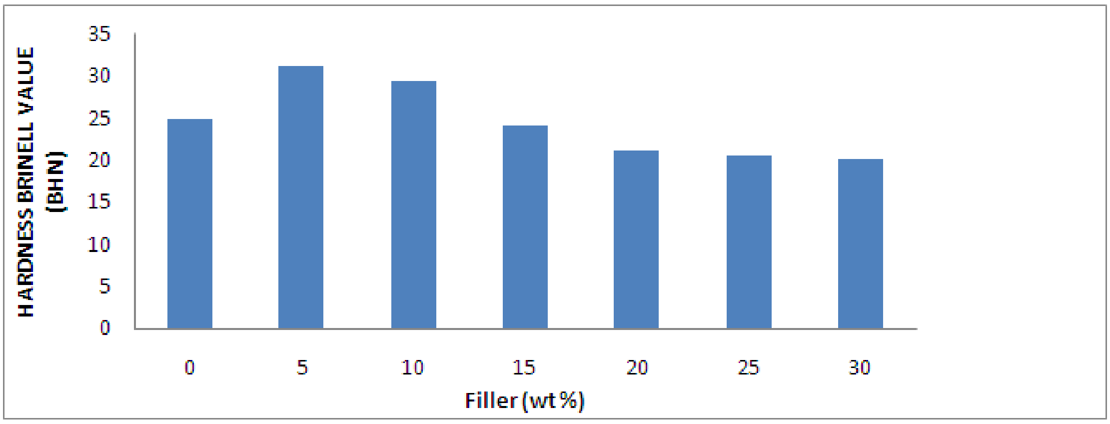

Figure 7. Chart of Brinell hardness against filler concentration

3.5. Tensile Strength

Figure 8 below shows the graph of ultimate tensile strength of the composite samples against its corresponding percentage reinforcement. It was observed that the highest UTS was at 30wt% filler concentration which was less than that of the control sample. Strength depends on effective stress transfer between filler and matrix, and toughness/brittleness is controlled by adhesion, various trends of the effect of particle loading on composite strength and toughness have been observed due to the interplay between these three factors, which cannot always be separated (Fu, et.al. 2013).

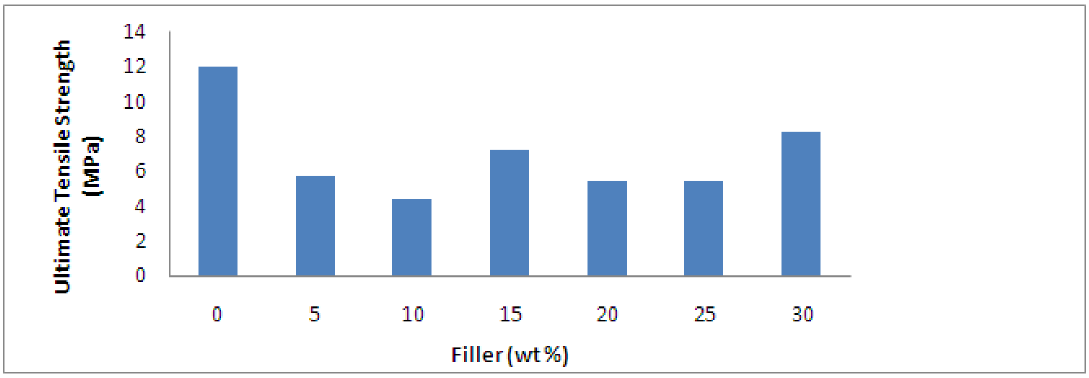

Figure8. Chart of ultimate tensile strength against filler concentration

Prediction of the strength of composites is difficult. The difficulty arises because the strength of composites is determined by the fracture behaviours which are associated with the extreme values of such parameters as interfacial adhesion (Luo, et.al.2014). Thus, the load-bearing capacity of a particulate composite depends on the strength of the weakest path throughout the microstructure, rather than the statistically averaged values of the microstructure parameters.

The good tensile strength at higher filler content for snail shell reinforcements could be attributed to better dispersion of the reinforcement in the polyester resin matrix, better wettability, absence of void or porosity and good interfacial bond.

3.6. Tensile strain at maximum load

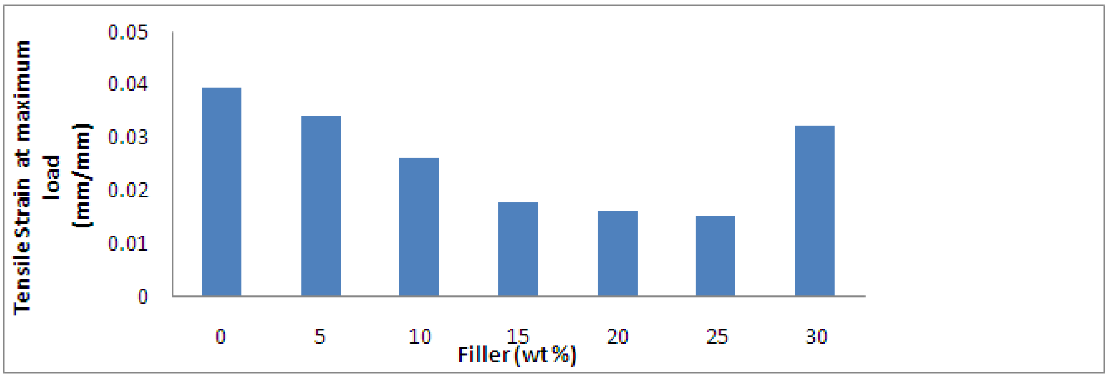

Figure9. Chart of tensile strain against filler concentration

Here the snail shell composite showed the highest tensile strain at maximum load at 5%. Further increase in the wt% of the particulate filler does not improve the strain.

IV. Conclusion

The mechanical tests carried out in this work include; flexural test, impact test, hardness test and tensile test, using varying proportions of snail shell reinforcement.

It was observed that the mechanical properties of polyesters can be greatly improved by reinforcing it with particulate snail shell filler. From figure 4, it is clear that unsaturated polyester/particulate snail shell composite with 20wt% reinforcement showed the highest resistance before failure by bending. The implication is that the snail shell reinforcements of 20% can be used in place of pure polyester for applications where flexibility is a major consideration.

From figure 6, it is evident that the composite sample with 5wt% reinforcement had the capacity to absorb the highest amount of energy before shattering relative to other samples the impact test was performed on. Therefore the particulate snail shell reinforced composite with 5wt% filler can be used in place of pure polyester where impact strength is a major factor.

From figure 7, it is evident that composite sample with 5wt% reinforcement had the highest surface hardness compared to other samples tested. This indicates that the 5wt% particulate snail shell reinforcement of unsaturated polyester can be used in place of the pure polyester for applications where surface hardness takes the top priority.

From figures 8 and 9, it is clear that the tensile properties of the composite were poor when subjected to tensile loading. It can be seen that tensile strength and strain of the pure polyester reduced when it was reinforced. This implies that the use of these composites should not be considered in applications that would subject them to tensile loading.

It can be concluded that particulate snailshell/polyester composite can be used in place of pure polyester depending on the filler content and user application.

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