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DEVELOPMENT OF EPOXY COMPOSITE REINFORCED WITH SNAIL SHELL ASH FOR ENGINEERING APPLICATION

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Abstract. Recent research indicate that snail shells are suitable reinforcement materials for the production of composite applicable in the automotive components such as pistons, connecting rods and brake pads. Snail shells reinforced with unsaturated polyester composites should be given priority in an automobile part where flexural strength, hardness and impact strength are of utmost importance, hence this study was carried out to explore the use of snail shell as filler for epoxy resin. The composite samples were prepared using snail shell ash (SSA) particles with average particle size of 75 µm, as reinforcement in an epoxy resin in the weight fractions of 0, 2, 4, 6, 8, &10wt% in an epoxy resin. Mechanical properties (tensile, flexural strength, hardness and wear) and the physical properties (bulk density, water absorption and porosity) of the developed composite was investigated. Snail shell ash particles incorporation shows beneficiary effect on the hardness, wear, density, water absorption and porosity. From the results, hardness was enhanced in the composites developed up to a threshold value of 4 wt. % SSA loading which shows that low SSA content is good for enhancement of mechanical properties. The result shows a great improvement in the wear and water repellant potential of the developed composite. The reinforcement was able to seal some void within the polymer matrix thereby accounting for drastic reduction in water absorption. The increase in the density of the composites further leads to an improvement in their hardness and toughness, which make these materials suitable for light weight applications. However tensile strength and flexural strength decreased upon SSA addition. Snail shell particles extracted from snail shell can be used as good reinforcing filler for epoxy resin.
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Keywords: Snails shells, reinforcement, composite, epoxy, snail

1. Introduction

A composite is a material formed of two or more physical components, offering much better properties than those of the single components, i.e., the matrix and the filler. Composites are usually manufactured from various types of matrices, such as polymers, metals, and ceramics. Among them, polymers have advantageous properties, such as chemical resistance, low density, good wettability, and easy molding into desired and engineered shapes. Therefore, polymers are used as matrices to a greater extent, compared to metals and ceramics [1]. It is also a material made from two or more different constituent materials having different physical or chemical properties which do not merge in the finishing structure, i.e., the individual constituents retain their properties. It is a combination of two materials in which one of the materials, called the reinforcing phase, is in the form of fiber sheets or particles and are embedded in the other material called the matrix phase. The primary functions of the matrix are to transfer stresses between the reinforcing fibers/particles and to protect them from mechanical and/or environmental damage whereas the presence of fibers/particles in a composite improves its mechanical properties such as strength and stiffness [2].

Polymer matrix composites (PMCs) are made by incorporating reinforcement into the matrix of thermoplastic and thermosetting materials. PMCs have broad applications due to their characteristics such as; lightweight, high stiffness, high strength, good corrosion resistance, lesser environmental degradation, excellent thermal insulation, good acoustic damping, excellent design flexibility, and nonmagnetic properties [3, 4]. The secondary phase is embedded in the matrix in a discontinuous form. The dispersed phase is usually harder and stronger than the continuous phase and is called reinforcement which serves to strengthen the composites and improves the overall mechanical properties of the matrix.

The ability of the epoxy ring to react with a variety of substrates gives the epoxy resins versatility. Treatment with curing agents gives insoluble and intractable thermoset polymers. Some of the characteristics of epoxy resins are high chemical and corrosions resistance, good Mechanical and thermal properties, outstanding adhesion to various substrates, low shrinkage upon cure, good electrical insulating properties, and the ability to be processed under a variety of conditions [5].
Snail shells are inspiring engineering materials in science and technology development which a lot of researchers have worked with in so many different ways. Snail shells have been used as raw materials to produce new ones or refine some other products. Snail shells have also been used to treat waste water and purification of aqueous solutions [6-10]. They are extensively used as reinforcing phases in the production of composite materials [11- 13]. Other areas that snail shells are being utilized as engineering raw materials are in the chemical, construction and automobile industries.
The objective of this paper is to bring to the engineering and technology community the usage of snail shell as reinforcement for the development of composite for engineering application.

2. Materials and Methods

Snail shell was sourced from a farm settlement in Ado-Ekiti, Ekiti State, Nigeria while the epoxy resin and hardener was purchased from a commercial supplier in Lagos, Nigeria. Figures 1(a) – 1(b) show the snail shell and the pulverized snail shell used for this study.

Figure 1a: snail shell

Figure 1b: Pulverized snail shell ash

2.1 Preparation of Snail shell ash: The snail shell was thoroughly washed with water to removed dirty particles such as sands and other contaminants and sun dried. It was then pulverized to a fine powder and hand sieved with a sieve of mesh size 75µm, the powdered shell was dried in an oven for 4 hrs. at about 100°C to reduce moisture content.

1.2. Development of Composite: The composite was compounded by adding the required volume of the epoxy with that of the particle (snail shell) for each formulation. This was done for particulate composition of control sample and (0, 2, 4, 6, 8 and 10) wt. % of snail shell addition. The required filler ratio of the snail shell particulate is added to the resin and stirred manually with a glass rod and mixed thoroughly until a good mixture is obtained. Thereafter, the required volume of the hardener is added to the mixture and stirred thoroughly, the volume ratio of epoxy to hardener is 3:1 according to previous works in literature. The mixture was poured into a mold and allowed to cure for 24 hrs. for the control sample (epoxy and hardener) and epoxy composite reinforce with snail shell ash (epoxy, hardener and snail shell). After curing, the composite block is stripped from the mold.

2.3 Mechanical Property Testing: Tensile, flexural, and hardness tests were used to determine the mechanical properties of the developed composite. The tensile properties and stress-strain behavior of the composites were evaluated with the aid of tensile test performed in accordance with ASTM D3038M-08 procedures (American Society of Testing and Materials, 2008). The test was performed using a universal testing machine, Instron incorporated USA model; Instron-series 3369 operated at a crosshead speed of 0.3 mm/mm and at a strain rate of 10^{-3}/s at room temperature [14]. Three-point flexural tests were used to determine the flexural strength of the recycled composites in accordance with the ASTM D7264M-07 standard [15] using a tensiometric universal testing machine with a crosshead speed of 0.3 mm/min and at a specific strain rate of 10−3/s. The hardness test was studied by a Vickers Micro hardness tester (Zwick/Roell Indented ZHV, at 19.6 g load, 10 s). Vickers hardness tests were performed on both control sample and reinforced samples surfaces. 10 indents were made on each surface avoiding boundary effects (i.e. keeping the appropriate distance from sample edges and between indentation marks), in well–separated and randomly selected regions to verify data consistency.

2.4. Wear Test. The wear-resistance test of the recycled composites was carried out on the Taber Abrasers Model ISE-AO16. The samples were mounted on a turn table platform that rotates at a fixed speed in accordance with [16]. The sample was weighed using an analytical weighing balance for the initial weight of the sample, after which it was fixed on the turn table which was made to rotate at 1000 rpm for 5 hours, and then, the samples were removed and weighed to obtain the final weight of the sample. The differences in the initial and final values of the samples were used to determine wear behavior.

2.5 Water absorption: water absorption test was carried out by immersing the developed composites into 250 cm^3 of distilled water for 7 days. The percentage difference between the initial and the final weight of each of the sample was computed and the data collected were used to determine the percentage of water absorption using the following formula:

$$\%\text{ water absorption} = \frac{\text{Final weight} - \text{Initial weight}}{Initial\ weight} \times 100 \quad (1)$$

3. Results

3.1 Mechanical properties

3.1.1. Ultimate Tensile Strength: Figure 2 shows the variation in tensile strength of the developed composite samples. It is observed that the ultimate tensile strength of unreinforced epoxy composite sample was 379.38 MPa which is higher than that of reinforced epoxy matrix composite samples, the reinforced samples with 6 and 10 wt. % has tensile strength of 346 and 292.4 MPa respectively while that of 8% wt. has the least tensile strength of 88.78 MPa. It was observed that addition of snail shell reduces the tensile strength as reported by previous works [17-18]. The poor tensile strength observed for the reinforced composite as compared with the unreinforced epoxy matrix in this work can be attributed to particle agglomeration, poor interfacial bonding at the matrix-particle interphase and poor adhesion of the reinforcing phase 19].

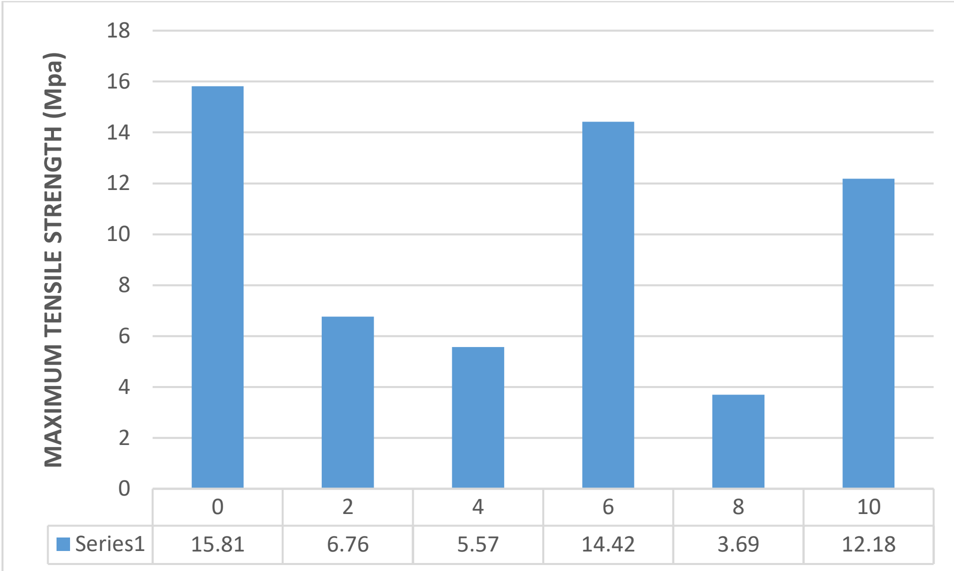

Figure 2 Variation in tensile strength of the developed composites and the control.

3.1.2 Flexural strength: Figure 3 shows the variation in the flexural strength of the developed composite, it is observed that the trend observed in tensile strength is similar to that of the flexural strength with the unreinforced sample displaying superior value (22.48 MPa) compared to the reinforced samples with 19.84 MPa and 19.66 MPa for 2 and 10 wt. %, respectively. This trend observed for all the mechanical properties conducted within the limit of these work can therefore be affirmed to be due to high particle agglomeration, Poor wettability resulting into poor matrix particle interfacial bonding. All these factors have been well reported by previous works [17-19]

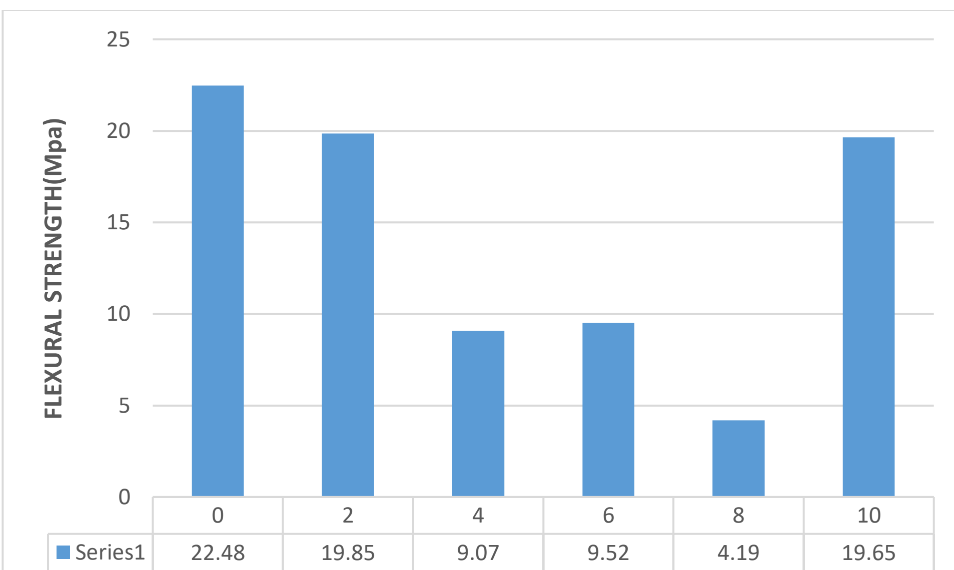

Figure 3. Variation in Flexural strength of the developed composites and the control

3.1.3. *Hardness Test:* Figure 4 shows the hardness value obtain for both unreinforced and snail shell particles reinforced epoxy samples. It is observed that the hardness value increases with increase in snail shell reinforcement (SSR) up to 4wt%reinforcement while drastic decline in hardness was observed from 6 wt. % up to 10 wt.%. The increase in hardness value obtain at 2 wt. % and 4 wt. % reinforcement respectively might be attributed to the high rigidity and hardness of the reinforcing phase particles which enhances strengthening as a result of is slow carrying capacity, and also to well dispersion of reinforcement and better interfacial bonding of the reinforcement [18]. However for samples having decline in hardness compare to the unreinforced sample despite increment in the reinforcing phase. The decline in hardness can be attributed to poor wettability and agglomeration [19]. It can further be affirmed within the limit of this research that 4 w. %t reinforcement gave the optimum hardness value.

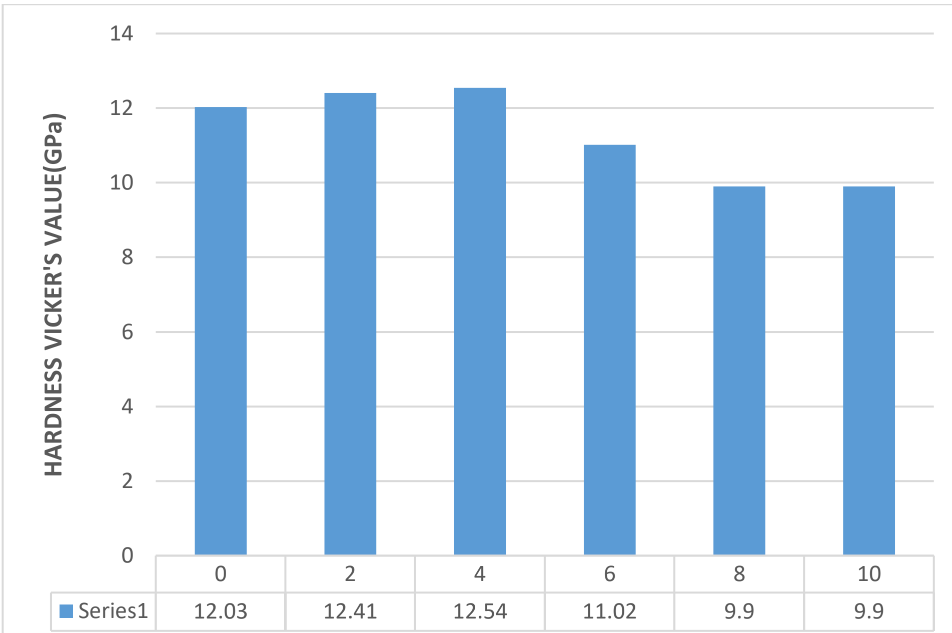

Figure 4. Variation in Hardness of the developed composites and the control.

3.2 Wear index: Wear index indicates the rate at which materials deteriorate when in contact with a sliding/rotating surface. The lower the wear index, the more resistant the material to abrasion. The variation in the wear index of the reinforced composites and the control is illustrated in Figure 5. The wear index was observed to be increasing from 0 wt. % to 6 wt.% but it greatly decreases from 8wt% to 10wt%. It was observed from the results that the higher the reinforcement weight applied the lesser the weight loss obtained. The presence of a significant amount of this hard and rigid phase from snail shell particles (SSP) in the epoxy matrix has brought about a great improvement in the wear of the developed composites, this finding was in agreement with previous submission where it was revealed that the addition of some selected agro waste aids the reduction in the abrasion effect on the developed composites [16]. It was observed that these bio-based composite materials can also be used as the floor panel in the interior of automobiles where good resistance to these environmental challenges will be encountered.

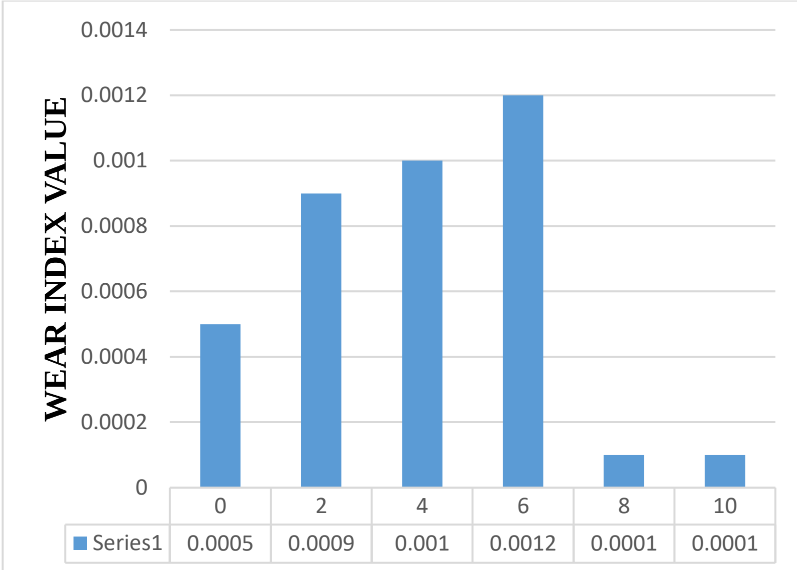

Figure 5. Weight loss of the developed composites and the control.

3.3. *Absorption and Porosity:* The variation in the ability of the developed composites to absorbed water and porosity is shown in figures 6 and 7 respectively, reinforced composite samples possessed low water absorption and porosity value as compared with the unreinforced epoxy matrix. This phenomenal might be attributed to the presence of snail shell ash particles (SSAP) as reinforcing phase sealing or covering the voids thus reducing the absorption of the samples. The presence of a significant amount of this hard and rigid phase from snail shell particles (SSP) in the epoxy matrix has brought about a great improvement in the wear and water-repellant potentials of the developed composites. Water uptake reduces as the amount of SSP increases because most of the pores/voids are being filled by the SSP, thereby reducing the number of possible pores that water can fill.

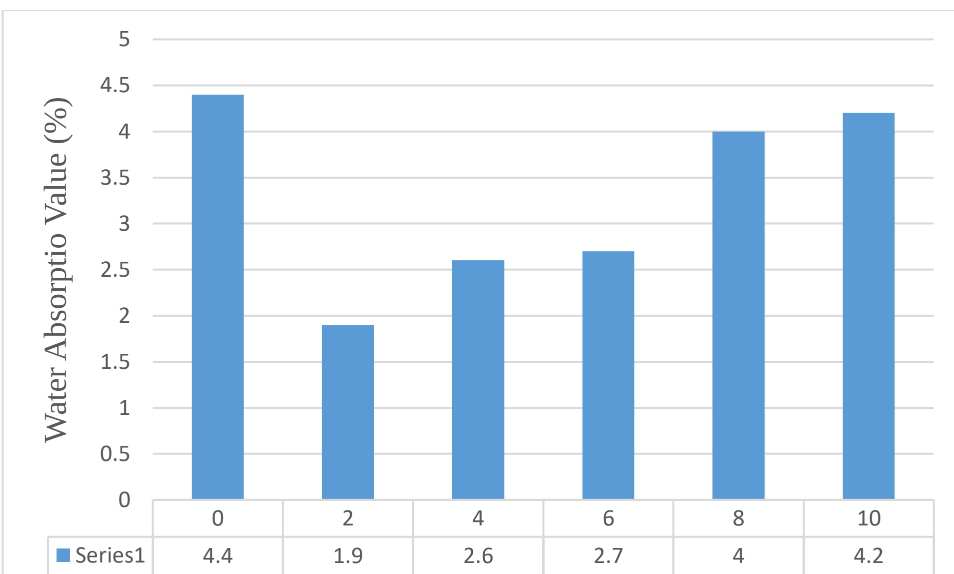

Figure 6. Variation in water absorption of the developed composites and the control.

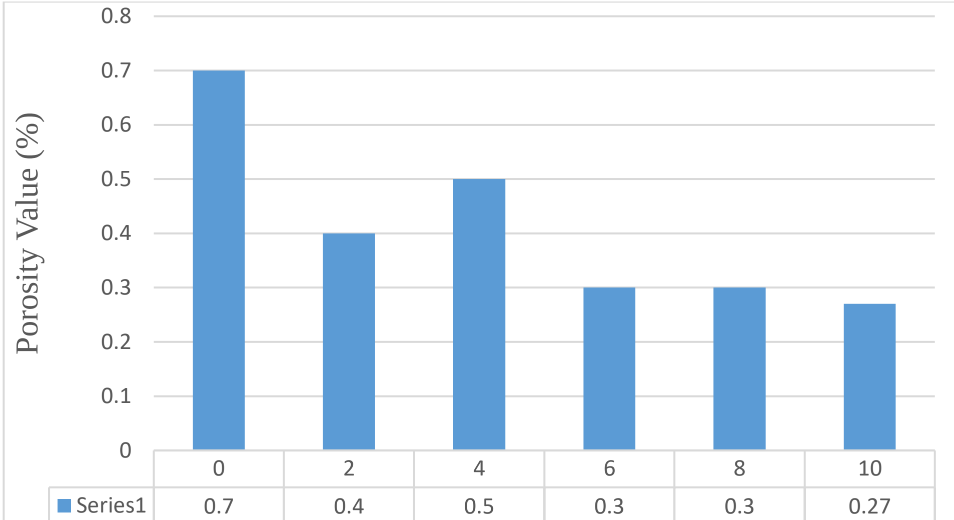

Figure 7. Variation in porosity of the developed composites and the control

4. Conclusions

The following conclusions were drawn from the results obtained from the properties evaluated: Tensile strength and flexural strength were found to suffer under higher SSA loading, the tensile strength values obtained where greater than their flexural counterparts. This trend can therefore be affirmed to be due to high particle agglomeration, Poor wettability resulting into poor matrix particle interfacial bonding and poor matrix particle properties.

Hardness was enhanced in the composites developed up to a threshold value of 4 wt.% SSA loading which shows that low SSA content is good for enhancement of mechanical properties. There was a great improvement in the wear and water repellant potential of the developed composite. The reinforcement was able to seal some void within the polymer matrix thereby accounting for drastic reduction in water absorption.
Snail shell particles can be used as good reinforcing filler for epoxy resin. However, a compromise must be reached in deciding the content of the snail shell ash to be incorporated so as not to sacrifice too much of its tensile and flexural strength.

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