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Influence of Periwinkle Shell Microparticle on the Mechanical Properties of Epoxy Polymer Composite

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ABSTRACT

The consumption of periwinkle, a species of small edible sea snail, produces residual shells. This paper investigated the effect of a powder of particle size that ranged from 4.39 µm to 100 µm, produced from a periwinkle shell, on the mechanical properties of the epoxy polymer composite. The changes in tensile strength of the polymer composites with the naturally occurring metal oxides of concentrations 0.5 to 1 wt % were studied. The results showed that the polymer composite possessed improved mechanical properties with the composite with 0.9 wt% periwinkle shell microparticle possessing the highest tensile strength and compressive strength, while the composite with 1 wt% periwinkle shell microparticle possessing the lowest impact energy and highest hardness. The mechanical properties have optimum improvement of up to 68% with the dispersion of 0.9 wt% of the powder into the epoxy polymer.

Key words: Dielectrics, epoxy, polymer composites, polymeric insulation, tensile strength.

INTRODUCTION

The quest for improved polymeric insulation brings about the idea of composite dielectrics. This involved the addition of micro/nano-additives in dielectric materials to create composite materials. Composite materials are multiphase materials in which the phase distribution and geometry have been controlled in order to optimize one or more properties. The intent of producing composite material is to make a material that combines the best properties. Several papers have reported progress made in the dispersion of additives in polymers to produce the composite dielectric materials [1].

Polymeric materials are important components of electrical insulation and epoxy family occupies a very important position in polymeric materials. Epoxies are class of thermostat materials used extensively in structural and specialty composite applications because they offer a unique combination of properties that are unattainable with other thermoset resins. Available in a wide variety of physical forms, from low viscosity liquid to high melting solids, they are amendable to a wide range of processes and applications. Epoxies offer high strength, low shrinkage, excellent adhesion to various substrates, effective electrical insulation, chemical and solvent resistance, low cost and low toxicity. They are easily cured without the evolution of volatiles or byproducts by a broad range of chemical species. Epoxy resins are also chemically compatible with most substrates and tend to wet surfaces easily making them especially well-suited to the composite application [2].

In an attempt to improve the mechanical properties of the epoxy polymer, the effect of different fillers dispersed in the polymer was investigated by various researchers. The effect of different weight percent (wt%) of TiO_2 nanoparticle on the mechanical properties of epoxy nanocomposites was studied by Bezy *et al* [3]. The epoxy nanocomposite has maximum tensile strength with 1wt% TiO_2 nanoparticle. The flexural strength decreases with an increase in wt% of TiO_2in the epoxy up to 5 wt%. The addition of 1 wt% nanoparticle decreased the impact strength of polymer composite and an increase in the concentration of the nanoparticle lead to an increase in the impact strength [3]. In another study, the mechanical properties of epoxy composites with ammonia-treated graphene oxide were evaluated by Park *et al*. [4]. The tensile and impact strength of the polymer composite was reported to have increased with an increase in the volume of ammonia solution used in the treatment of the graphene oxide. They attributed this behaviour to the rigid interfacial bonding formed in the presence of an amine curing agent [4]. The mechanical properties of epoxy resin reinforced with silica/glass fiber when compared with glass fiber/epoxy showed that the tensile strength, elastic modulus and flexural modulus of silica added glass fiber/epoxy composites increased significantly [5]. Composites with silica were reported to have reached the maximum mechanical strength at 7.5% silica loading. Silica-epoxy Nanocomposites were reported to have Young’s modulus, tensile stress, and yield stress that increased linearly with the increasing particle loading [6]. In another work, an attempt was made to study the effect of fly ash as a filler material in epoxy glass fiber reinforced composites. Fly ash of mass ranging from 2 g to 10 g was dispersed into epoxy glass fiber reinforced composites. While the tensile strength of the composites with 6 g fly ash was reported to have a maximum value of 27.1790 MPa, the composite with 4 g fly ash has the maximum flexural strength of 110.497MPa [7].

The effect of periwinkle shell powder on the mechanical properties of polypropylene and polyester composites was studied at high filler content (10-50 wt %) [8]. It was reported that the addition of the filler in the polypropylene matrix led to an improvement in the mechanical properties of the polypropylene composite and that the composite can broaden the application scope of polypropylene. The addition of 30 wt% periwinkle shell in polyester was reported to have produced a polyester composite with the highest tensile and flexural strength [9].

For polymer composite used as polymeric insulation, oxides of metals are often used as fillers at low filler content. Aside from acting as insulators, polymers serve as a mechanical support in the power system.

Quite a number of works has been performed in an attempt to improve the mechanical strength of epoxy. The most common technique used to achieve this involves the reinforcement of the epoxy matrix with micro- and nano-particle fillers. Some of the commonly used fillers are alumina, silica, mica, talc, organoclays, nanoclays, carbon nanotubes and TiO_2 [10-12]. Functionalized nanosize alumina particles as nanofiller were identified to have significantly improved the mechanical properties of the epoxy composite [10]. In an investigation on the mechanical properties of the nano SiO_2 epoxy nanocomposite, the addition of the nanoparticle in the base polymer resulted in an increase in the mechanical strength of the epoxy nanocomposite. Maximum enhancement of the tensile strength was achieved with the 3 wt % nano SiO_2 loading [11]. The mechanical properties of epoxy/D-clay nanocomposites were studied as a function of D-clay loading of 1 to 4wt% [12]. The best mechanical performance (tensile strength) was also obtained for 3 wt% D-clay containing. This significant increase in mechanical performance was linked to the well dispersed D-clay in the epoxy matrix and strong interfacial bonding which enhanced the fracture toughness, leading to higher strength compared with the neat epoxy [12].

While synthesis of oxides of metals can be costly, micro- and nano-particles from naturally occurring materials such as clays have been used as fillers in epoxy as the base matrix.

There has been previous work on the effect of periwinkle shell powder on the mechanical properties polymer composites at high filler content [8, 9]. Periwinkle is another type of seashell animal. It is a species of small edible sea snail that is consumed in large quantity in Nigeria. It is scientifically known as *Littorina Littorea* and it is classified within the family *Littorinidae*. Its consumption produces residual shells which posed an environmental hazard. The shell is a natural ceramics which contained several metal oxides used in material applications such as filler in concrete production. This paper seeks to explore the effect micro-particles produced from the periwinkle shell on the mechanical properties of the epoxy polymer at low filler content.

MATERIALS AND METHODS

Sample preparation

Epoxy resin of grade A and a curing hardener of grade B were used as the matrix. The filler was produced from the periwinkle shell as shown in Plate 1a. The Periwinkle shells were obtained from the local market in Zaria, Nigeria. The obtained shells were washed in hot water to remove contaminants and remains of the animal. This was followed by washing the shells with acetone. They were then dried in an oven at 100 ºC for 48 hours to completely remove moisture from it. It was then ground into powder as shown in Plate 1b. The required volume of resin and hardener were measured and the neat polymer sample was made by mixing them in the ratio 3 [epoxy resin]: 1[hardener] in the beaker and by stirring the mixture in a beaker with a magnetic stirrer. The mixture was degassed in a vacuum oven at a temperature of 40 ˚C for about 8 minutes. The mixture was transferred into a mould and was pre-cured in a vacuum oven. The pre-cured polymer of thickness 2 mm was cured at room temperature for 24 hours. The same procedure was followed to produce the polymer composite but with the addition of the periwinkle shell powder in the hardener before mixing with the resin. In the preparation on the polymer composite samples, 0.5 wt%, 0.6 wt%, 0.7 wt%, 0.8 wt%, 0.9 wt% and 1 wt% of the powder was mixed with hardener properly using magnetic stirrer after which it was added to the measuredepoxy resin [13].

Plate 1: Samples (a) Periwinkle Shell (b) Periwinkle shell powder

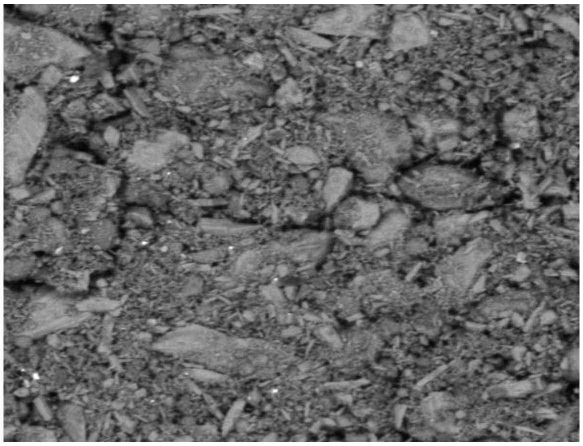

Plate 2: SEM microstructure of periwinkle shell powder at the magnification of 25000 X

Tensile Test

The tensile test was performed using the Monsanto Tensometer machine. The machine has two jaw clamps. A test sample cut into a dumb-bell shape was positioned on the jaws and the clamp was used to grip the test sample. The wheel attached to the clamp was turned to increase the tension on the test sample until the sample fractured. The force and elongation were then recorded for each sample. The readings obtained were used in the calculation of the sample tensile strength (MPa).

RESULTS AND DISCUSSION

The powder contained oxide of metals with 81.8% of the composition as CaO and the remaining 18.2% consists of MgO. Al_2O_3, SiO_2, Fe_2O_3, SO_3, etc [14]. The particle size of the powder was evaluated to be 4.39 μm to 100 μm, from SEM microphotograph. The SEM image was obtained using Phenom ProX Desktop scanning electron microscope (SEM) equipped with an energy dispersive spectroscopy system.

Table 1 presents the average value of the obtained results from the tensile test of the sample only and the samples containing periwinkle shell powder while Figure 3 compares the tensile strength of the polymer samples on a bar chart. The chart displayed the influence of the percentage composition of periwinkle shell micro-particle powder in the polymer composites. It is evident that the tensile strength of the polymer increased with the addition of the periwinkle shell micro-powder. A further increase was also observed in the polymer composite with an increase in the percentage composition of the micro-particle in the polymer. An increase in the tensile strength was observed from polymer only to the samples with the shell microparticle composition of up to 0.9 wt%. A decrease in the tensile strength was observed with the addition of 1 wt% of shell microparticle. It is not certain if 0.9 wt% powder produced a composite with the optimum performance or possible agglomeration was responsible for the lower tensile strength of that sample. Agglomeration may make the material to become brittle andthis could result in failure with lesser tension.

Table 1: Tensile, compressive, hardness and impact test results

Composition (%)	Tensile strength (MPa)	Compressive strength (MPa)	Hardness Value (HV)	Impact strength (J)
0.0	31.94	54.31	10.77	5.38
0.5	42.85	76.94	22.28	4.74
0.6	64.05	99.26	27.92	4.48
0.7	76.45	124.68	31.62	3.94
0.8	97.27	135.01	35.48	3.56
0.9	100.94	137.73	37.32	2.68
1.0	77.44	104.78	40.62	1.94

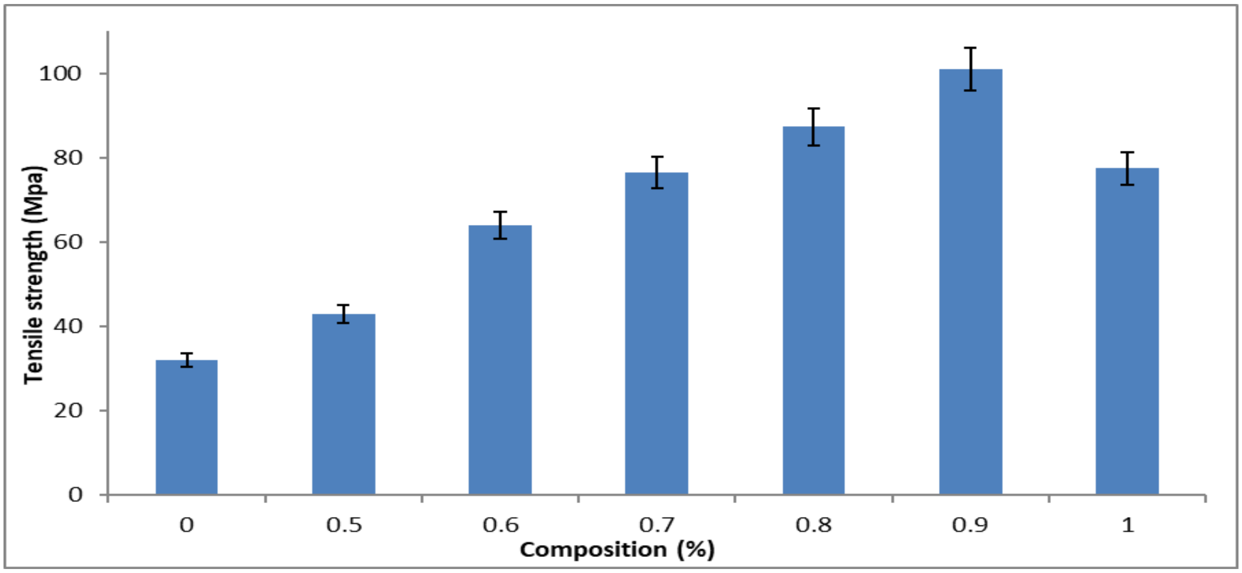

Figure 1: Profile of Tensile strength of the sample's composition in different percentage powder addition.

The compressive strength test shows a similar result as shown in Figure 2. But a steady increase in the compressive strength was obtained up to 0.7%. The further increase shows relative stability of compressive strength to 0.9% concentration. Increasing the content of the powder to 1% shows a decrease in the compressive strength.

The Hardness test result in Figure 3 shows a continuous increase as the concentration of the particles increases while the impact value decreases with an increase in the composition of the powder as shown in Figure 4.

The improved tensile strength recorded from the addition of the periwinkle shell powder results from an increase in the tensile strain of the respective polymer composites.An increase in the quantity of the dispersed powder resulted in an increase in tensile strain. But the dispersion of 0.5wt%powder resulted in a decrease in the tensile strain and a corresponding decrease in tensile strength.

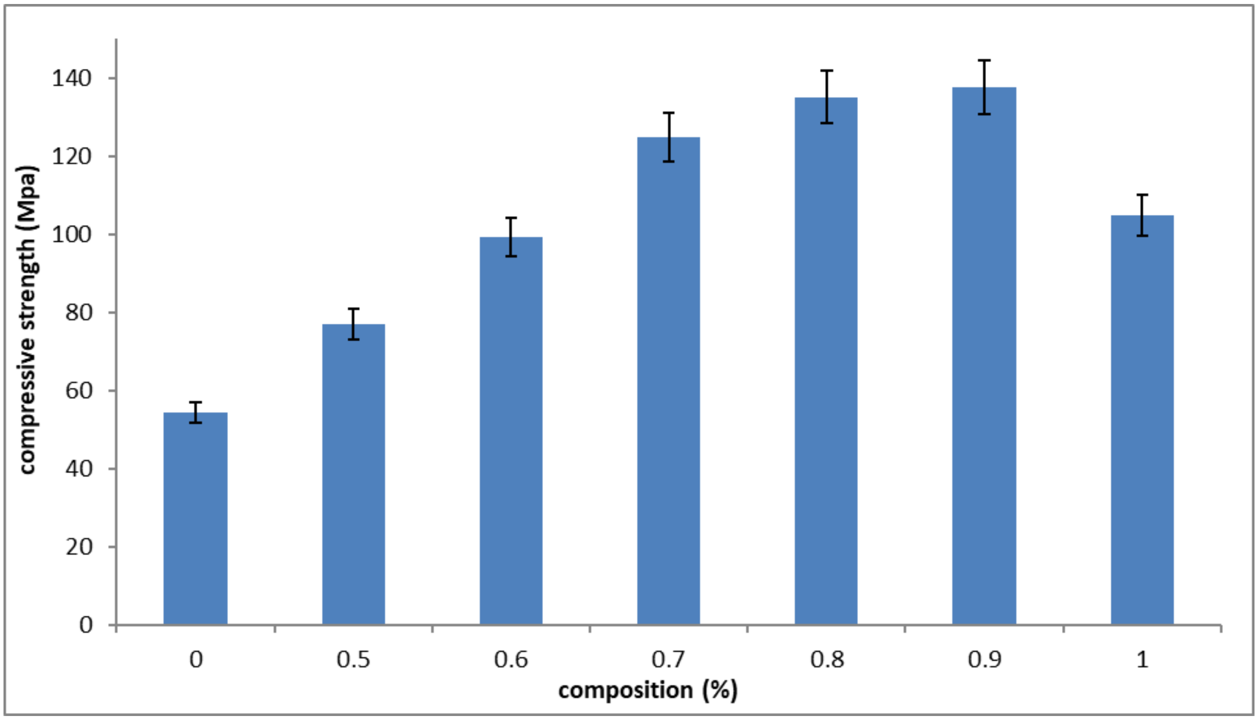

Figure 2: Profile of Compressive strength of the sample's composition in different percentage powder addition.

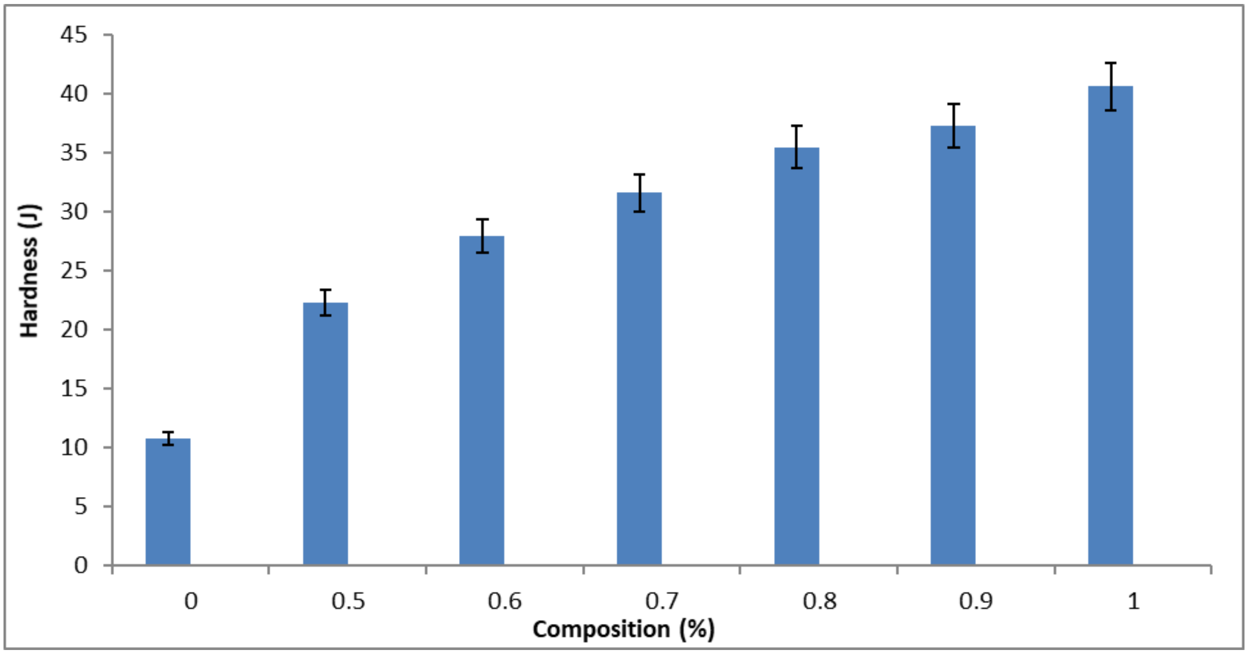

Figure 3: Profile of Hardness Value of the sample's composition in different percentage powder addition.

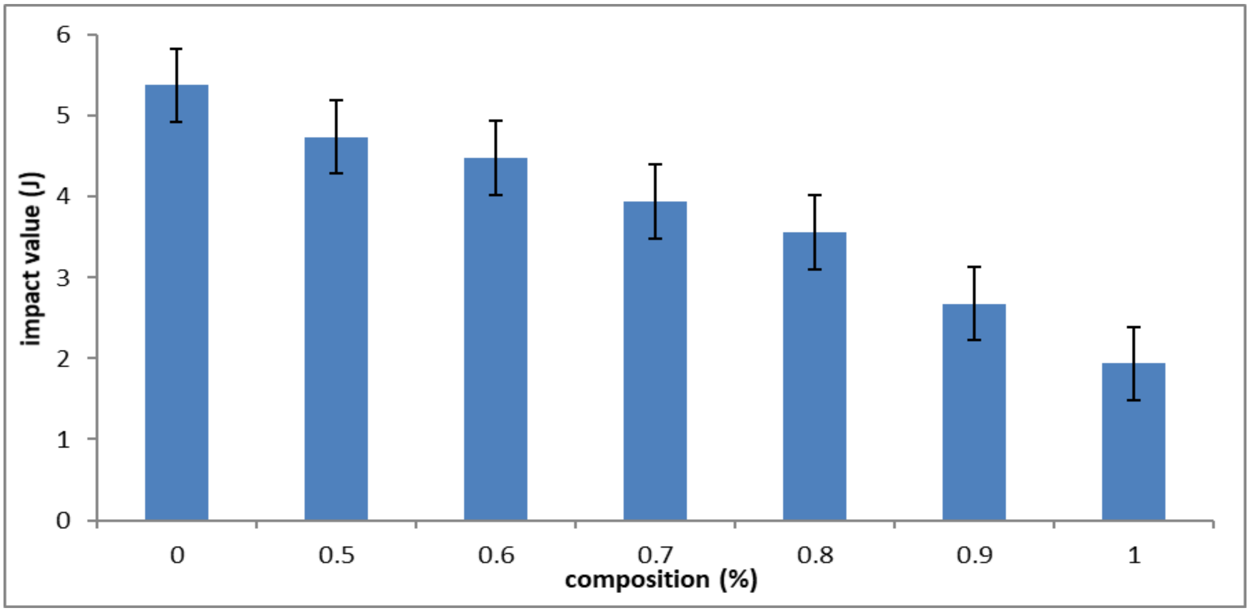

Figure4: Profile of Impact strength of the sample composition in different percentage powder addition.

The tensile and compressive strength of the samples with different percentage composition as displayed in Figures 1 and 2 respectively indicate that the tensile and compressive strength increased with the increasing percentage of periwinkle shell powder. A maximum tensile strength was achieved with 0.9wt% periwinkle shell. It can be seen from the Figures that the samples have the highest value of 100.94 and 137.73 MPa for tensile and compressive strength respectively with the addition of 0.9 wt% periwinkle shell powder. These properties decreased to 77.44 and 104.78 MPa for tensile and compressive strengths with the addition of 1 wt% periwinkle shell powder. This was an indication that the composite material has optimum mechanical properties with the addition of 0.9% micro-powder. The increase in the tensile and compressive strengths is due to a better interfacial bonding (i.e. two bodies in contact held together by intermolecular forces) which was attributed to the strength of polymer composites. Therefore, the higher values in tensile and compressive strengths obtained at 0.9 wt% are attributed to the uniform distribution of the periwinkle shell powder into the epoxy resin matrix.

The sample with 0.9 wt% periwinkle shell powder filling gave the best mechanical properties as a result of a very good dispersion of the powder fillings. The polymer composite acquired its optimum mechanical strength with the addition of 0.9 wt% periwinkle shell powder. Beyond 0.9 wt%, the composite polymer began to lose its improved mechanical strength. The drop in the mechanical properties as seen in the sample with 1 wt% particle fillings may have possibly resulted from agglomeration due to the presence of excessive periwinkle shell powder in the polymer matrix.

It is clear from Figure 3 that the hardness values of the composite polymer samples increased as the percentage of periwinkle shell powder increased in the epoxy matrix. The increase in hardness of the polymer composite may be due to an increase in the percentage of the hard elements present in the periwinkle shell powder.

It is also clear from Figure 4 that the impact energy (energy absorbed per unit area under the notch) values of the polymer composite samples decreased as the percentage of periwinkle shell powder in the epoxy matrix. The presence of the hard element and the reinforcing of periwinkle shell powder with epoxy play a significant role in decreasing the impact strength of the polymer composite.

CONCLUSION

The mechanical properties of periwinkle shell powder filled epoxy have been studied in this work at low filler content.

- ✓ The tensile strength of the polymer composites varied from 1.94 MPa to 10. 94 MPa and the maximum tensile strength of 10.94 MPa was obtained for the polymer composite with 0.9 wt % of periwinkle shell powder.
- ✓ The compressive strength of the polymer composites varied from 4.31 MPa to 13.73 MPa and the maximum compressive strength of 13.73 MPa was obtained for the polymer composite with 0.9 wt % of periwinkle shell powder.
- ✓ The hardness of the polymer composites increased with an increase in the filler content with a maximum hardness of 10.62 when the polymer composite contained 1wt% of periwinkle shell powder.

- ✓ The impact strength of the polymer composites decreased with an increase in the filler.
- ✓ This is an indication that the dispersion of periwinkle shell powder has a significant effect on the mechanical strength of the epoxy polymer.

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