

Experimental Evaluation of Carbon Nanoparticle Addition on the Mechanical Properties of Banana Fiber Micro Particle Reinforced Epoxy Matrix Composites

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Abstract. In this experiment we evaluated the mechanical characteristics on the carbon nanoparticle addition of banana fiber micro particle reinforced epoxy matrix composites. The composite are manufactured in the compression moulding machine. The 0.5, 1 and 1.5 wt% of carbon nanoparticles added with the 30wt% composites. The tensile, flexural, impact and hardness properties are tested on the composites. The test result shows that the maximum tensile, flexural, impact and hardness strength values are identified in the 1.5wt% nano particle addition composites. The values are 55.53 MPa, 51.76 MPa 0.27J and 71.5 N. The morphology studied exposed the distribution of nano particle and manifest the interfacial strength between the particles and the matrix in the composites.

Keywords: carbon nanoparticles, banana fiber micro particles, epoxy resin, mechanical properties, morphological study.

Introduction

The nano science is the multidisciplinary area of research that escalates in the materials development areas. In recent days the technology development is based on the specific properties of nanoparticles like chemical, thermal and mechanical. These properties are investigated by arranging the particles on the nano size into macro size. The different types of nanoparticles are metal, ceramic, and polymeric. The nanoparticles have distinctive physical properties due to their high surface contact area. The tensile, flexural and impact strength of the materials dependent on their size, shape and structure [1]. The study evaluates the tensile, flexural and hardness properties and shows significant improvement in the polymer composites because of nanoparticle addition [2]. The mechanical properties have improved by the addition of alumina nanoparticles of the short Glass/Carbon fiber reinforced epoxy composites. The result proved that the dispersion of particles in the resin enhances the impact, flexural strength and modulus values [3]. The author investigates that the mechanical properties have been enhanced due to the effect of nanotechnology [4]. The author investigates the nanoparticle addition with polymer filled composites on the mechanical and tribological behaviors. The results shows that the mechanical and wear properties are found to increase with increasing filler materials [5]. The addition of Al₂O₃ nano particle with the pandanus, coconut bunch fiber reinforced composites were prepared and studied. The result shows that the increase in nano particle content with natural fiber composites gives the better result than the without addition of nanoparticle reinforced composites [6]. This study evaluates the tensile, flexural and thermogravimetric characteristics of flax fiber reinforced epoxy composite with the addition of nano TiO₂. The maximum weight percentage was maintained at 28wt%. The TiO₂ nanoparticle added to the fiber such as 0%, 0.5%, 0.7% and 0.9% by weight. The experimental result shows that the mechanical properties has improved by adding (0.7%) nanoparticles percentage in the composites [7]. The effects of nano-silica (NS) particle (3 wt%) on the mechanical properties of intraply and woven fiber reinforced carbon/Kevlar/epoxy hybrid composites shows the significant improvement in the composites [8]. The author studied the effect of natural fillers such as rice husk, wheat husk and coconut coir on the mechanical properties of glass fiber reinforced epoxy and polyester composites. The result identifies the natural fillers provided better improvement in the polyester based composites than epoxy resin matrix composites [9]. This research evaluates the influence of nano-Titania loading (0, 0.5, 1.0, and 2.0 % of volume fraction) on the mechanical and water absorption characteristics of jute fiber reinforced epoxy matrix composites. The nano-Titania notably gives the better result in the jute fiber reinforced epoxy composite [10]. The alumina filler reinforced epoxy composites were investigated on the dynamic mechanical behavior which increases significantly because of the addition of nanoparticle [11]. The jute fiber hybrid with hemp fiber reinforced composites and nano titanium oxide are studied. It proved that increased infiller content (6wt %) has been given the highest mechanical strength [12]. In this study used carbon nanoparticle and banana fiber micro particles used as the reinforcement material and the epoxyis the resin to prepare the composites. Then the mechanical properties have been analyzed in the various percentages of nanoparticle

composites. The improvement in results is keenly watched and finds the reasons for the improvement.

1. Experimental details

1.1 Materials

The materials used in this experiment are resin (LY556) and hardener (HY951) for the composite preparation. The banana plant is the source of fibers which is collected from the banana sheath. The collected fibers are cut into chopped fiber. After that the chopped fibers are crushed into particles by using a mixer grinder machine and are sieved manually at an average size of 1-10 microns. The resin and the hardener are purchased through Seenu & Company, Coimbatore, Tamil Nadu, India. The carbon nanoparticles are collected from the LMP R&D Laboratory, Pallipalayam, Coimbatore. Tamil Nadu, India.

1.2 Preparation of composites



Fig. 1 (a) The mixing of carbon nano particles, acetone solution and epoxy resin. (b) Shows the sonicator used to stir the mixer. (c) Shows the oven used to heat the mixer for evaporating the acetone solution. (d) Shows the three different types of composites (i) 0.5wt % addition of nano particle composites, (ii) 1.0 wt % addition of nano particle composites (iii) 1.5 wt % addition of nano particle composites.

Table 1. Composites

30wt % Composites (Particle + Resin+Hardener)	
Banana fiber micro particle	90 grams
Resin	220 ml
Hardener	22 ml
Carbon nano particle wt%	
0.5 wt%	1.5 grams
1.0 wt%	3 grams
1.5 wt%	4.5grams

1. Mechanical testing

2.1 Tensile test

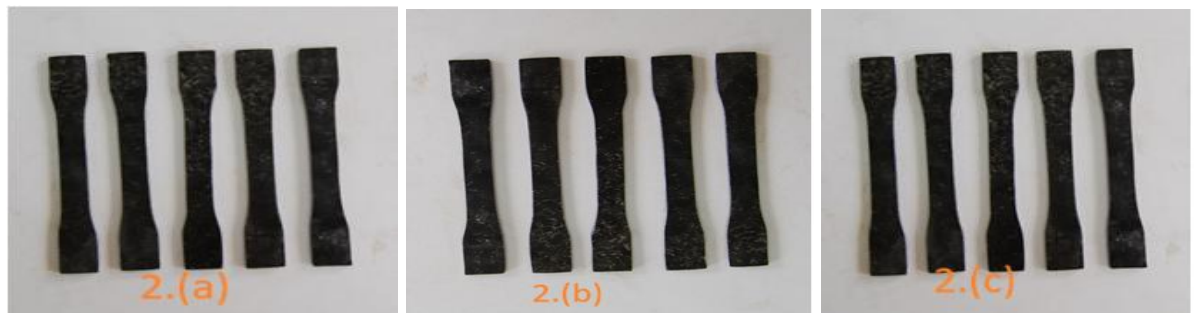


Fig. 2. - (a) The tensile test specimen composites of 0.5wt% carbon nano particle addition (b) Shows the tensile test specimen composites of 1.0wt% carbon nano particle addition (c) Shows the tensile test specimen composites of 1.5wt% carbon nano particle addition

Fig. 2 shows the nano particle addition 0.5,1.0 and 1.5wt% of composite specimen for tensile test. The material subjected to tensile force in the longitudinal direction for measuring tensile strength. The specimen is in the gripper at both ends in the tensile tester. The tensile force is applied on each end of the specimen until it fractures. The graph is plotted against the load vs. length. The ASTM standard (ASTM D 638) is followed during the tests conducted on the universal tensile tester model DTRX-30KN DEEPAK POLY PLAST PVT LTD.

2.2 Flexural tests

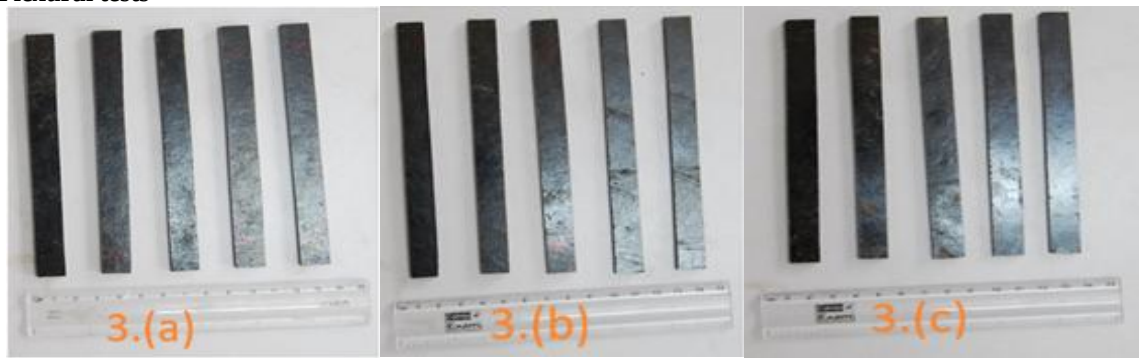


Fig. 3. - The flexural test specimen of (a) 0.5 wt % addition of carbon nanoparticle composites (b) 1.0 wt % addition of carbon nanoparticle composites (c) 1.5 wt % addition of carbon nanoparticle composites.

Fig. 3 shows the addition of nano particle composite such as 0.5, 1.0 and 1.5wt%. Flexural test determines the force required to bend the specimen. The specimen is placed horizontally over the lower support of two points of contact. Then a force is applied over the specimen through single point of contact until the specimen fails. Flexural modulus is calculated from the slope of the stress vs strain curve. The flexural tests were carried out in the universal tensile tester (DTRX-30KN DEEPAK POLY PLAST PVT LTD). The ASTM D790 standard has been implemented in the test.

2.3 Impact test

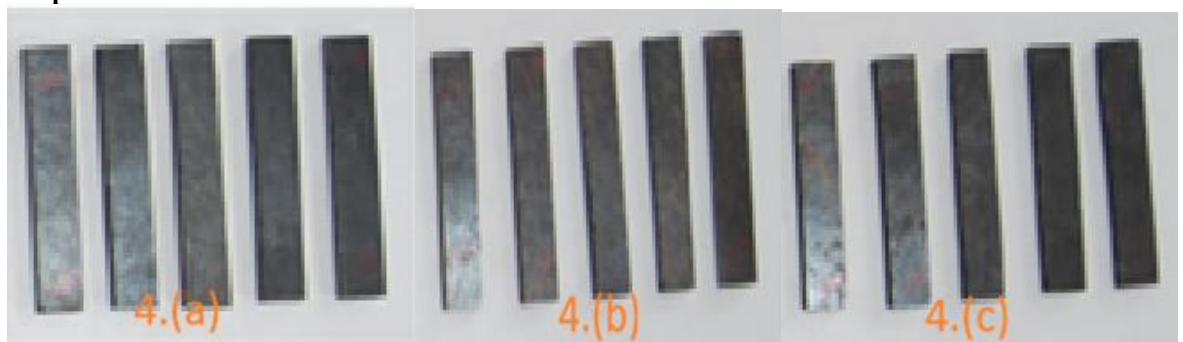


Fig. 4. - The impact test specimen of (a) 0.5 wt % addition of carbon nanoparticle composites (b) 1.0 wt % addition of carbon nanoparticle composites (c) 1.5 wt % addition of carbon nanoparticle composites

Fig. 4 shows the nano particle addition (0.5, 1.0 and 1.5wt%) of composites for impact test. Impact tests conducted to determine the toughness in the material. It is the energy received by the material in the plastic state. The specimen is laid vertically on the grippers, which hold the specimen tightly, and the pendulum is blown from one side which strikes it with kinetic energy. The energy absorbed by the specimen before the fractures are recorded on the scale for calculations. The test is performed using Izod-Charpy Impact tester machine (Deepak Poly Plast Pvt Ltd) followed by ASTM D256 standard. The experiments were conducted at room temperature.

9.7 Hardness test

The hardness values (HS) measured by shore D test method. The needle shaped indenter tip forced over the composite specimen. The depth of indentation denotes the hardness. The indentation was taken at five different places on the composites and average values were noted. The tests are performed with ASTM D2240 standard.

2.5 Morphology study using SEM

The morphology study was carried out by Scanning Electron Microscope. It identifies the distribution of particles and the interfacial strength of the particles and resin matrix. The voltage used in this experiment is 10 KV.

2. Result and Discussions

3.1 Tensile test

Fig. 5 shows the tensile strength value of three different types of composites (0.5wt%, 1.0wt% and 1.5wt% carbon nano particle addition)

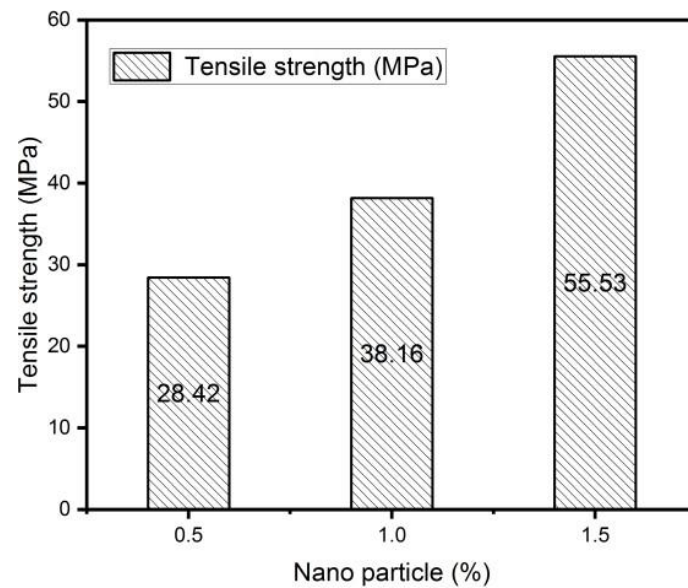


Fig. 5. - The tensile strength value of three different types of composites (0.5wt%, 1.0wt% and 1.5wt% carbon nano particle addition)

The Fig. 5, shows the tensile test result of carbon nanoparticle addition with banana fiber micro particle reinforced epoxy composites. The higher tensile strength identified in the 1.5% addition of nanoparticle composites (55.53 MPa). It is 48.82% higher than the 0.5% addition of nanoparticle composites. The increase in nanoparticle content increases the strength of the composites. The adhesion between the particles and the resin are high is the reason for the high strength. The nanoparticles act as a filler to distribute evenly throughout the composites [13]. So stress transfers from the particles and the resin are good enough also the reason for the maximum tensile strength [14]. The surface contact area of the nanoparticle is more; this is the cause for better strength. The minimum tensile strength value points out in the 0.5% addition of nanoparticle composites due to the reason that the distribution of particle content is not even and the agglomeration of the particle decreases bonding strength of the particle with the resin [15].

Fig. 6 shows the tensile modulus value of three different types of composites (0.5wt%, 1.0wt% and 1.5wt% carbon nano particle addition)

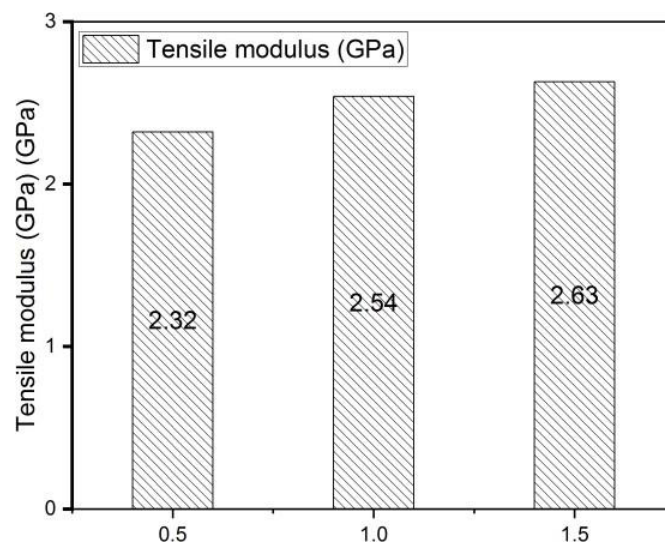


Fig. 6. - The tensile modulus value of three different types of composites (0.5wt%, 1.0wt% and 1.5wt% carbon nano particle addition)

The modulus value of the various percentages of nanoparticle composite are shown in Fig. 6. It shows that the maximum modulus values are in 1.5% addition of composites. That is 3.4% and 11.79% higher than the 1.0% and 0.5% addition of nano particle composites. Here the stress value gradually increases the strain values.

3.2 Flexural strength

Fig. 7 shows the flexural strength value of three different types of composites (0.5wt%, 1.0wt% and 1.5wt% carbon nano particle addition).

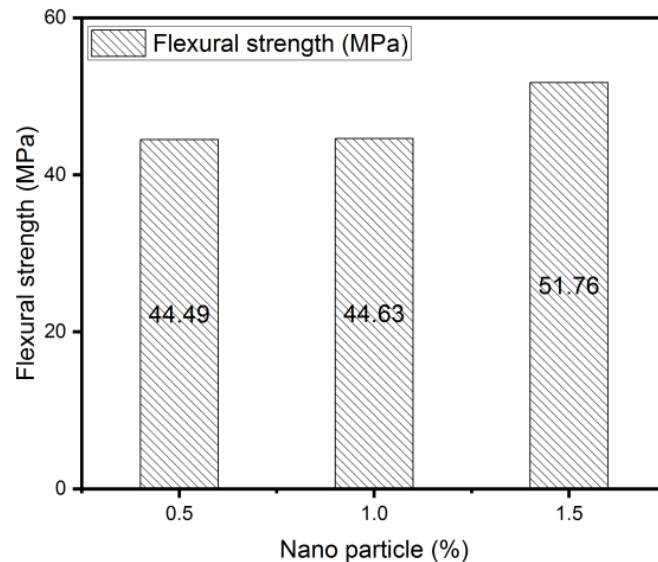


Fig. 7. - The flexural strength value of three different types of composites (0.5wt%, 1.0wt% and 1.5wt% carbon nano particle addition)

The flexural strength values of the composites are shown in Fig. 7. The nanoparticle mixed with the epoxy matrix enhances the interface area more rigidly is the cause for better flexural strength [16]. The load carried from the particle to the resin is high because the better interface between the particle and the matrix is rich. Due to the reason that the composites absorb more loads and bending of composite is limited. The maximum flexural strength marked in the addition of nanoparticles 1.5% in the composites (51.76MPa) which is 14.05 % higher than the composites addition of 0.5% nanoparticle content and 13.76% higher than the 1% addition of nanoparticle composite. The addition of nanoparticles dispersed evenly and created the strong interfacial strength between the particles. The presence of nanoparticles restricts the motion of polymer molecules to enhance the interlocking properties is the reason for higher strength.

Fig. 8 shows the flexural modulus value the composites.

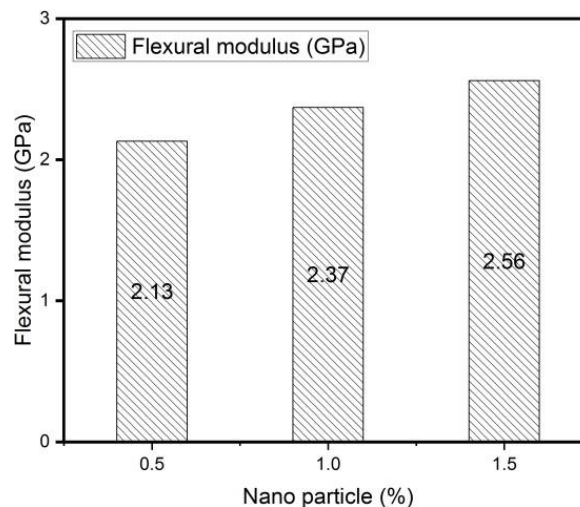


Fig. 8. - The flexural modulus value of three different types of composites (0.5wt%, 1.0wt% and 1.5wt% carbon nanoparticle addition)

The 1.5% addition of nano particle composites shows higher modulus value than the other two nanoparticle additions of composites. This is 7.42 and 16.80 % higher than the 1.0 and 0.5% in addition of nano particle composites.

3.3 Impact test

Fig. 9 shows the impact strength value of three different types of composites (0.5wt%, 1.0wt% and 1.5wt% carbon nano particle addition).

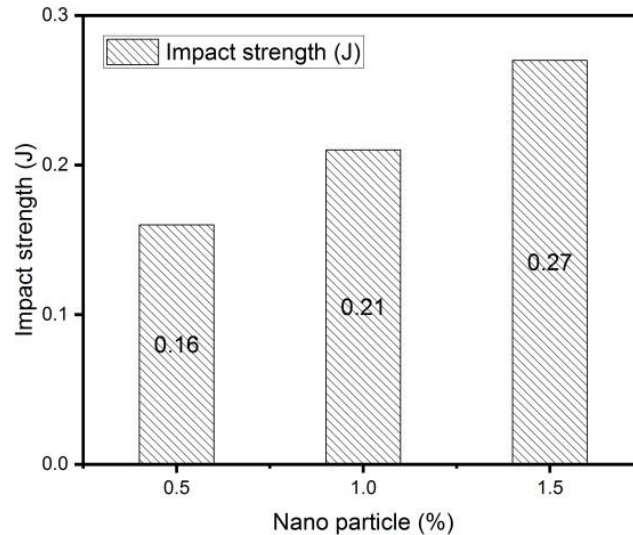


Fig. 9. - The impact strength value of three different types of composites (0.5wt%, 1.0wt% and 1.5wt% carbon nano particle addition)

Fig. 9 shows the impact energy absorbed by the nanoparticle addition of banana fibermicro particle reinforced composites which showed maximum value (0.27J) in the 1.5% nanoparticle addition of composites that is 40.74% higher than the 0.5% nanoparticle addition of composites and 22.22% higher than the 1% nanoparticle addition of composites. This is due to the dispersion of nanoparticles with the banana fiber micro particle in the matrix.

3.4 Hardness test

Hardness test is the test for identifying the materials properties to use for specific purposes.

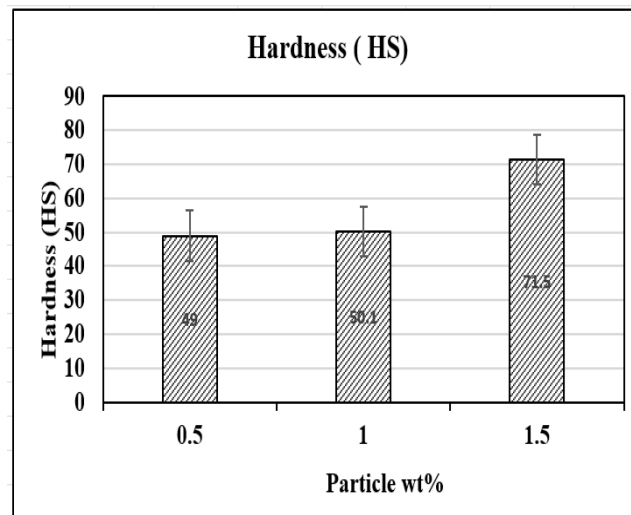


Fig. 10. - The hardness value of three different types of composites (0.5wt%, 1.0wt% and 1.5wt% carbon nano particle addition)

Fig. 10 shows the hardness of various percentage carbon nanoparticles (0.5%, 1% and 1.5%) in the polymer composites. The highest hardness value (71.5) is predicted in the addition of 1.5% carbon nanoparticle composites. That is 31.46% higher than the 0.5% added nanoparticle composites and 29.93% higher than the 1% addition of nanoparticle composites. The hardness values are increased by adding the particle content in the composites. The

addition of particles increases the resistance force in the material.

3.5 Morphology study using SEM

Fig. 11 shows the surface morphology of (a) 0.5 % nanoparticle addition composites, (b) 1.0 % nanoparticle addition composites, (c) 1.5 % nanoparticle addition composite.

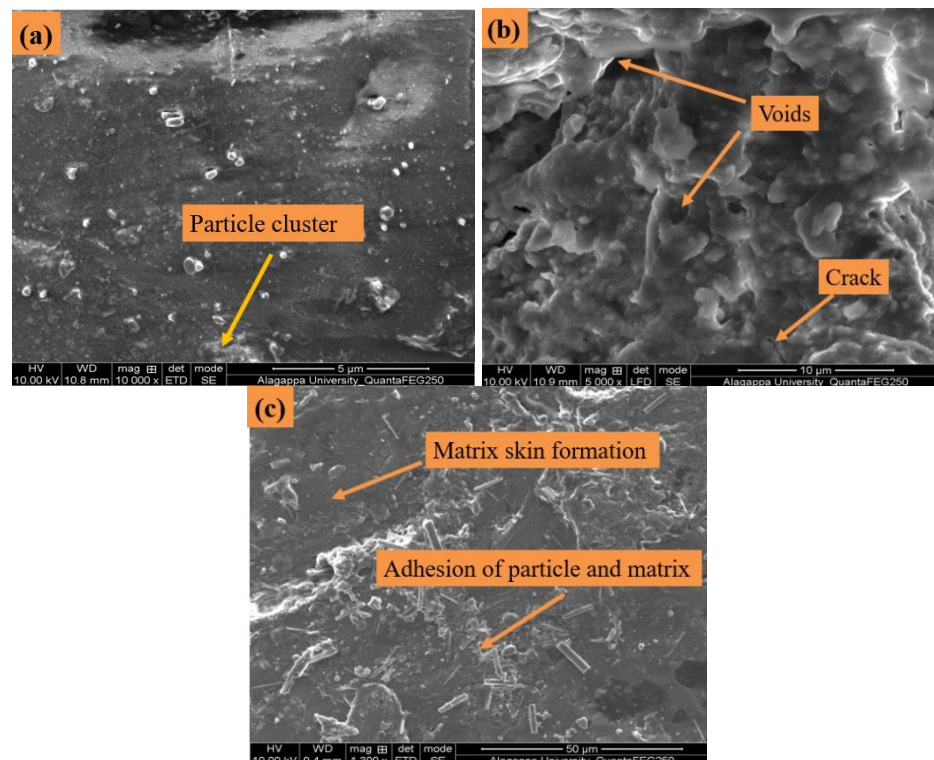


Fig. 11. - The surface morphology of (a) 0.5 % nanoparticle addition composites, (b) 1.0 % nanoparticle addition composites, (c) 1.5 % nanoparticle addition composite.

Fig.11 (a) shows the addition of 0.5% nanoparticle with banana fiber micro particle reinforced epoxy matrix composites. It shows the particle clusters in some places which is the evidence of improper distribution of nanoparticles in the matrix. This is the main reason for the less strength. Fig.11 (b) exhibits the addition of 1% nanoparticle with banana fiber micro particle reinforced epoxy matrix composites. The voids and cracks identified in some locations are the reason for the minimum strength. Fig.11 (c) shows the addition of nanoparticles 1.5% with banana fiber micro particle reinforced epoxy matrix composites. It shows the matrix skin formation in some areas and also the interfacial adhesion between the particles is the cause for higher strength in the composites.

Conclusion

In this experimental research investigated the effect of carbon nano particle addition of banana fiber micro particle reinforced epoxy matrix composites on the mechanical properties. The research revealed several core findings regarding the performance of the composites. Particularly the 1.5 wt% carbon particle addition of banana fiber micro particle reinforced epoxy matrix composites exhibit superior tensile, flexural, impact and hardness strength compared to 0.5, 1.0 wt% addition of carbon nano particle composites. enhanced performance can be obtained to the 1.5wt% carbon nano particle composites, the uniform distribution of nano particles and the compatibility of the particle and the matrix. which enhances the interfacial strength between the reinforcement and the matrix, thereby increasing the strength and hardness of the composites. Scanning electron microscopy (SEM) analysis strengthen these results, showing that the adhesion between the addition of carbon nano particle (1.5wt%) of the banana fiber micro particle and epoxy matrix is significantly effective. The carbon nano particle acts as a interlocking substance enhances the bonding between the particle and the matrix, contributing to the improved mechanical properties observed.

Overall, the experimental results of this research underscore the potential of 1.5wt% addition of carbon nano particle as a viable reinforcement and act as a filler material in epoxy composites. These materials contributed the combination of high tensile, flexural, impact and hardness strength.

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