Morphology of Aluminum Oxide (Al\textsubscript{2}O\textsubscript{3}) Nanoparticles and Their Effect on the Micro Structural and Mechanical Properties of Carbon Fiber-Reinforced (CFR) Epoxy Nanocomposites

P. Mansoor, B.W. Sandeep Kumar

Abstract: The main aim of this article is to investigate the effect of inclusion of Aluminum oxide (Al\textsubscript{2}O\textsubscript{3}) nano particles at varied percentage of weights into the carbon fiber-reinforced (CFR) epoxy composites, and evaluating the Mechanical properties for flexure, Impact and Tensile strength. The Aluminum oxide (Al\textsubscript{2}O\textsubscript{3}) is included into various percentages starting from 1 to 5 wt% and spread homogeneously throughout the epoxy resin by ultrasonication process. The CFR-Al\textsubscript{2}O\textsubscript{3} nano composites are prepared through layup technique and healed by vacuum bagging method. The mechanical properties such for flexure and ultimate tensile strength showed better properties due to the presence of Al\textsubscript{2}O\textsubscript{3} nanoparticles, while response for CFR-Al\textsubscript{2}O\textsubscript{3} nano composites increased at 2 wt% addition of Al\textsubscript{2}O\textsubscript{3} nano particles, and further reduction has been seen at 5wt% due to an greater static effect.

Keywords: flexure strength, Carbon fiber-reinforced epoxy nanocomposites, impact strength, sonication, tensile strength, vacuum bagging, Aluminum oxide nanoparticles

I. INTRODUCTION

Since from past decades man prepared various polymers extending from normal rubber to complex such as thermo plastics. The polymer had been used in a modern period as an alternative medium, for various applications in aerospace and automotive field because of their excellent strength-weight ratio. As the polymer possess light weight, they have been attracted more by the modern world. Carbon Fiber reinforced polymer (CFRP) composites had been used in many structural applications because of their strength and stiffness with light weight and excellent erosion properties\textsuperscript{[2,3]}

The humans use of various naturally founded materials for improving the material properties by the formation of composites. The strength of the material composites depends upon the atomic and molecular levels ranging at the nanoscale. The nanoscale particles for material ranges from 1 to 100nm, at the nano range the material possessed better features \textsuperscript{[5]}. In organic metals and metal type oxide nano particles are utilized in many commercial uses as they have shown better for Electrical, Thermal, agentic, unique surface and optical features. An series of polymers and inorganic metal oxides has been used for better mechanical, electrical, Magnetic characteristics. Al\textsubscript{2}O\textsubscript{3} nano composites have gained more amount of attention in many profitable uses because of their excellent properties of reflecting UV radiations.

The present paper puts forth the outcomes of the research work proposed to see the effect of addition of inorganic metal oxide (Al\textsubscript{2}O\textsubscript{3}) nano particles as a filler to a carbon Fiber reinforced polymer (CFRP) composites.

II. EXPERIMENTAL METHOD

A. Materials

A viscosity medium of Diglycidyl ether of Bisphenol-A (DGEBA) type (Araldite LY556) is choosen as a matrix resin along with hardener (Ardur 5200). The matrix resin and Ardur 5200 are obtained from Hunstman corporation India. Unidirectional plain carbon fiber of 420g/m\textsuperscript{2} is used as a continuous reinforcement obtained from china. The Al\textsubscript{2}O\textsubscript{3} nanoparticles are used as fillers is processed from china with the average particle size of 50nm. The TEM image of Al\textsubscript{2}O\textsubscript{3} nano particles is shown in figure1. Showing the nano surface particles.

Figure 1: TEM image of 50 nm Al\textsubscript{2}O\textsubscript{3} nano particles.
B. Ultrasonication

Ultrasonication is a method used for inclusion for dispersion of Al₂O₃ nano particles with an epoxy resin. The required amount of epoxy resin is collected in a glass beaker and weighted amount of nano Al₂O₃ nano is presented. The mixed solution is prepared with the help of the stirrer. This method is done at room temperature for half an hour. It gives rise in viscosity of the resin and forms the Epoxy- Al₂O₃ nanogel. The ultrasonication arrangement (Make: Q700, Q sonic) is utilized in the current research as displayed in figure 2. Hardener Aradur 5200 is added to the nanogel solution and mixed thoroughly to form nanogel solution.

![Figure 2: Ultrasonication process source from Google](image)

C. Composite Fabrication

The composites are fabricated by a hand layup technique. At starting the unidirectional carbon fiber mat material was made to form six square pieces of size 320* 320mm squares of about thickness of 3mm compatible for various tests and are weighted using microelectronic balance. An alike percentage of nanogel solution is weighted and utilized for preparation of composite laminate. An amount of discharging agent is added to a foil followed by the application of a thin layer of nanogel solution over each layer of carbon fiber mat material is positioned and further coat of nanogel solution is applied homogeneously above the carbon fiber mat and the process gets continued for remaining five fiber mats. Finally, over the sixth carbon fiber mat nanogel solution is applied. The handmade material is then preserved using vacuum bagging to remove air which is trapped between layers. The below figure 3. Shows the vacuum bagging process is adopted in the current work.

![Figure 3: Vacuum bagging technique source from google](image)

D. Composite Preparation

Several composites are prepared with the differences in a nano Al₂O₃ filler content with resin. The filler percentage is varied from 1 to 5% in every iteration. The composite preparation is shown in below table 1.

<table>
<thead>
<tr>
<th>Specimen structure (by Wt% )</th>
<th>Composite Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% epoxy + 50% carbon fiber + 0% Al₂O₃</td>
<td>ALG0</td>
</tr>
<tr>
<td>49% epoxy + 50% carbon fiber + 1% Al₂O₃</td>
<td>ALG1</td>
</tr>
<tr>
<td>48% epoxy + 50% carbon fiber + 2% Al₂O₃</td>
<td>ALG2</td>
</tr>
<tr>
<td>47% epoxy + 50% carbon fiber + 3% Al₂O₃</td>
<td>ALG3</td>
</tr>
<tr>
<td>46% epoxy + 50% carbon fiber + 4% Al₂O₃</td>
<td>ALG4</td>
</tr>
<tr>
<td>45% epoxy + 50% carbon fiber + 5% Al₂O₃</td>
<td>ALG5</td>
</tr>
</tbody>
</table>

Table 1: Composite Number code

III. MECHANICAL TESTS

E. Mechanical Property Evaluation

The presence of Al₂O₃ nano particles spread with the epoxy resin matrix is investigated through (AFM) technique. The mechanical flexural strength of the specimens were done on Roell Z020 UTM wich is having capacity of 15KN, with cross head speed of 1mm/min. The Impact strength was carried by Roell HIP50P pendulum impact tester. The notch specimen for Izod Impact were done as per ASTM256 standards. The mechanical Tensile strength tests were conducted by universal testing machine of 100KN capacity. Flat rectangular specimen was cut from the composite for evaluating tensile strength.
IV. RESULTS AND DISCUSSION

A. Inclusion Analysis

The inclusion of Al₂O₃ nanoparticles into epoxy matrix will be demonstrated by 3D topographic Atomic force microscopy images shown above in Fig 4. Close examination of AFM images proposes that there is unvarying and advanced spreading of Al₂O₃ nanoparticles over top surface of the composite protects which showed as bulge spots for Al₂O₃ at (Figure 4C, D). As the process Al₂O₃ percentage increased the spots on the AFM images reduced which specifies that there is less concentration of Al₂O₃ over the surface of the composite laminate (Figure 4C-E, F). This is because of agglomeration of Al₂O₃ nanoparticles leads to higher loads that made to stop the movement and spreading above the surface of the specimens. In this article the fibres are made and results were calculated on tensile and Impact strengths.

B. Flexural Strength

The flexure strength of the prepared specimen are shown in Figure 5 as increase of Al₂O₃ nanoparticles showed a declination of the flexure strength of CFRP specimen. This is because of equal spreading of nano Al₂O₃ within the epoxy matrix. The results showed that the flexure strength for ZEG2 is more as compared with other nano specimens. While ALG4 and ALG5 filled with 4 and 5 wt% of Al₂O₃ Nano filler it reduced the bond formation between the matrix and filler and showed the Delamination.

C. Impact Strength

From the stress vs strain showed in figure 7. We can illustrate that the specimen ALG0 is subjected to tensile loading for which it stand to maximum force of 400Mpa, while ALG1 with stand to a Maximum tensile strength of about 300Mpa, after that it started cracks. For the specimen ALG2 which showed Maximum tensile strength of 350Mpa, which is the best among other specimen sample composites. While ALG3, ALG4 showed maximum of 280Mpa,250Mpa and ALG5 showed Maximum of about 245Mpa. ALG2 is the best amongst Al₂O₃ filled nanocomposites, the other specimen samples ALG3, ALG4, ALG5 showed decreasing trend in their tensile strength because of Agglomeration. The SEM images showed for ALG0 matrix adheres to fibers and showed superior tensile strength. And at ALG2 the fibers are pulled out with minimum brittle fracture. While ALG4 and ALG5 filled with 4 and 5 wt% of Al₂O₃ Nano filler it reduced the bond formation between the matrix and filler and showed the Delamination.

Figure 4: Atomic force microscopy of the Specimen.

Figure 5: Flexural strength of the specimen sample

Figure 6: Tensile strength of the specimen

Figure 7: Stress vs strain curves of the specimen

V. CONCLUSION

1. Mechanical Flexural and tensile strength of ALG0 is highest among several other type of nanocomposites specimens, which showed the inclusion of Al₂O₃ Nanofiller have shown negative effect on their properties.
2. The inclusion of Al₂O₃ Nano particles to the epoxy will give adequate hardiness to the matrix there by giving good Impact strength for CRP- Al₂O₃ Nanocomposites.
3. It has found that 2wt% of Al₂O₃ Nano particle for ALG2 specimen showed enhancement in Mechanical properties compared to ALG3, ALG4 and ALG5.

REFERENCES


10. Synthesis and characterization of zinc oxide (Z) filled glass fiber reinforced polyester composites

AUTHORS PROFILE

Mansoor.P research scholar from school of mechanical Engineering at Reva University Bangalore, Karnataka. India.

B. W. Sandeep Kumar, Assistant professor Vemu Institute of Technology, Chittoor Dist, Andhrapradesh.