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Morphology of Aluminum Oxide (Al_2O_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_2O_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_2O_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_2O_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_2O_3 nanoparticles, while response for CFR-Al_2O_3 nano composites increased at 2 wt% addition of Al_2O_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 [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 [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_2O_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_2O_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^2 is used as a continuous reinforcement obtained from china. The Al_2O_3 nanoparticles are used as fillers is processed from china with the average particle size of 50nm. The TEM image of Al_2O_3 nano particles is shown in figure1.

Showing the nano surface particles.

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* Correspondence Author

P. Mansoor*, Research Scholar, Mechanical department, Reva University, Bangalore, Karnataka, India.
Email: mansoor.reva@gmail.com

B. W. Sandeep Kumar, Assistant professor Vemu Institute of Technology, Chittor Dist, Andhrapradesh, India.
Email: sandeepkumarbw@gmail.com

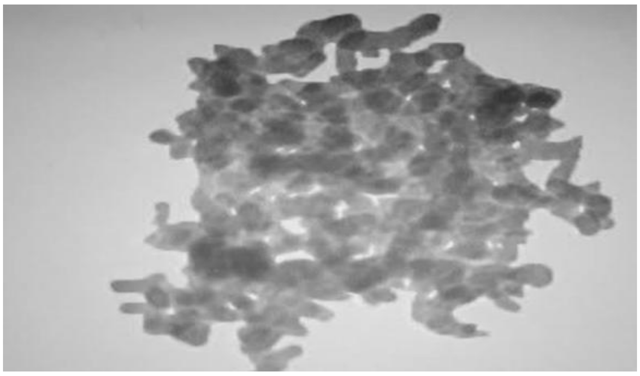


Figure 1: TEM image of 50 nm Al_2O_3 nano particles.

B. Ultrasonication

Ultrasonication is a method used for inclusion for dispersion of Al_2O_3 nano particles with an epoxy resin. The required amount of epoxy resin is collected in a glass beaker and weighted amount of nano Al_2O_3 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- Al_2O_3 nanogel. The ultrasonication arrangement (Make: Q700, Q somica) 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.

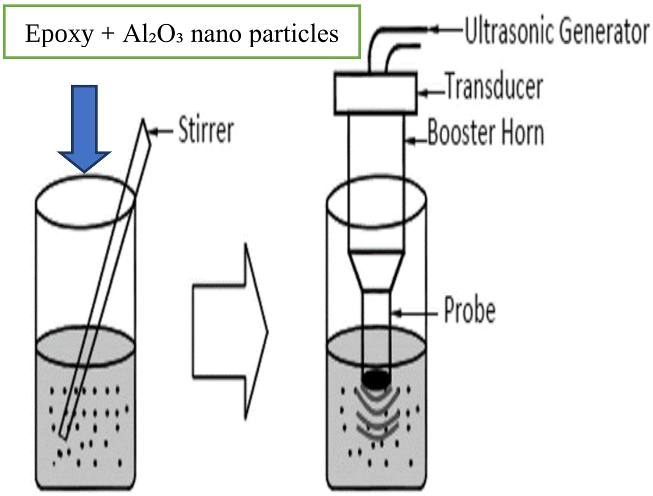


Figure 2: Ultrasonication process source from Google

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.

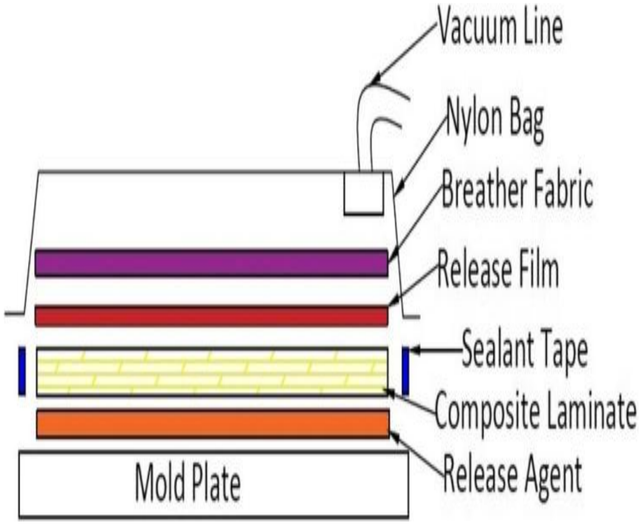


Figure 3: Vacuum bagging technique source from google

D. Composite Preparation

Several composites are prepared with the differences in a nano Al_2O_3 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.

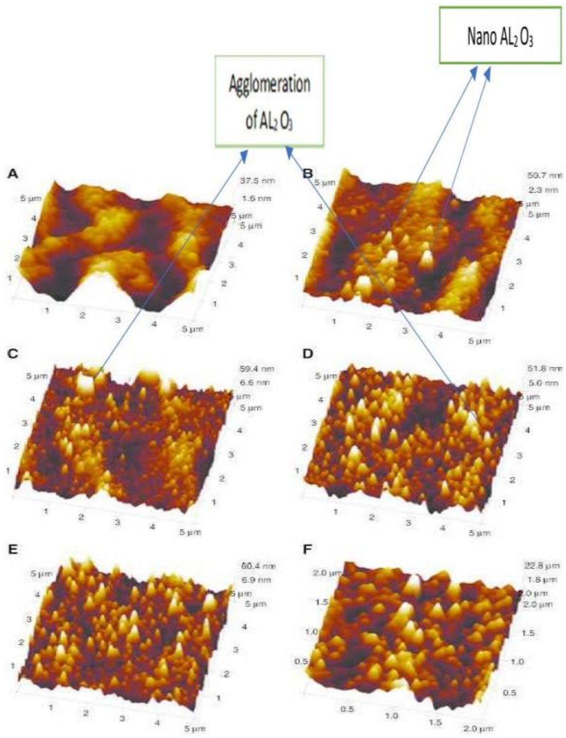
Specimen structure (by Wt%)	Composite Number
50% epoxy + 50% carbon fiber + 0% Al_2O_3	AL G0
49% epoxy + 50% carbon fiber + 1% Al_2O_3	AL G1
48% epoxy + 50% carbon fiber + 2% Al_2O_3	AL G2
47% epoxy + 50% carbon fiber + 3% Al_2O_3	AL G3
46% epoxy + 50% carbon fiber + 4% Al_2O_3	AL G4
45% epoxy + 50% carbon fiber + 5% Al_2O_3	AL G5

Table 1: Composite Number code

III. MECHANICAL TESTS

E.Mechanical Property Evaluation

The presence of Al_2O_3 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.



A-SPECIMEN COMPOSITE ALG0 B- SPECIMEN COMPOSITE ALG1

C- SPECIMEN COMPOSITE ALG2 D- SPECIMEN COMPOSITE ALG3

E- SPECIMEN COMPOSITE ALG4 F- SPECIMEN COMPOSITE ALG5

Figure 4: Atomic force microscopy of the Specimen.

IV. RESULTS AND DISCUSSION

A. Inclusion Analysis

The inclusion of Al_2O_3 nanoparticles into epoxy matrix will be demonstrated by 3D topographic Atomic force microscopy images where shown above in Fig 4. Close examination of AFM images proposes that there is unvarying and advanced spreading of Al_2O_3 nanoparticles over top surface of the composite protects which showed as bulge spots for Al_2O_3 at (Figure 4C, D). As the process Al_2O_3 percentage increased the spots on the AFM images reduced which specifies that there is less concentration of Al_2O_3 over the surface of the composite laminate (Figure 4C-E, F). This is because of agglomeration of Al_2O_3 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 Al_2O_3 nanoparticles showed an declination of the flexure strength of CFRP specimen. This is because of equal spreading of nano Al_2O_3 within the epoxy matrix. The results showed that the flexure strength for ZEG2 is more as compared with other nano specimens. That showed more filler percentage addition of Al_2O_3 makes to agglomerate and declines the mechanical strength of the composite.

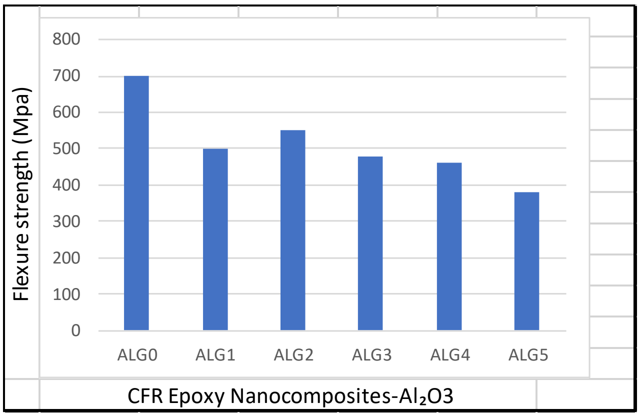


Figure 5: Flexural strength of the specimen sample

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 with 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 Al_2O_3 filled nanocomposites, the other specimen samples ALG3, ALG4, ALG5 showed decreasing tend 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 Al_2O_3 Nano filler it reduced the bond formation between the matrix and filler and showed the Delamination.

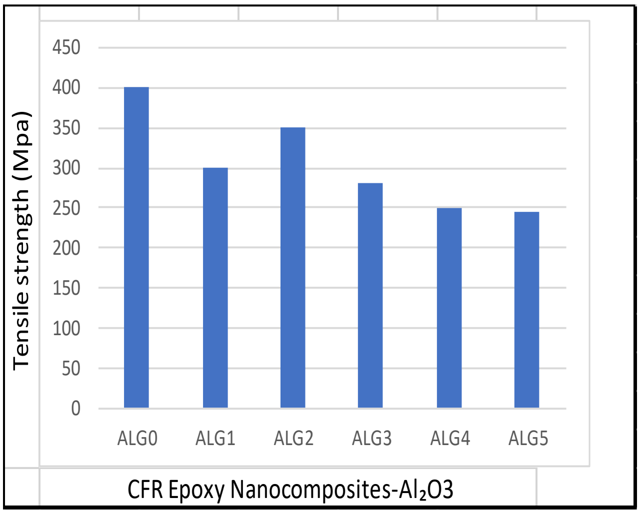


Figure 6: Tensile strength of the specimen

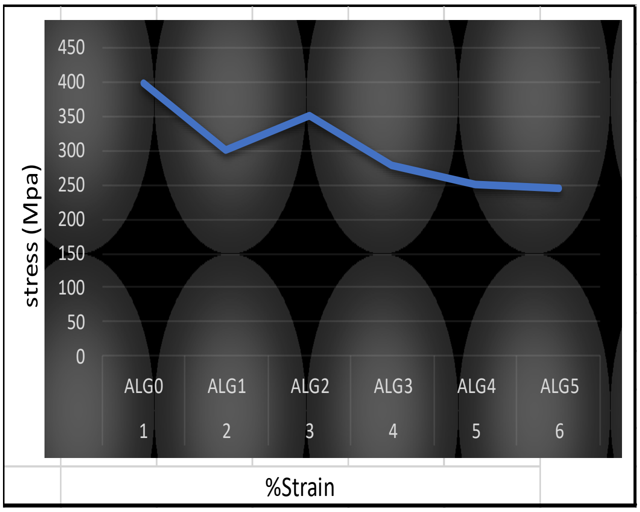
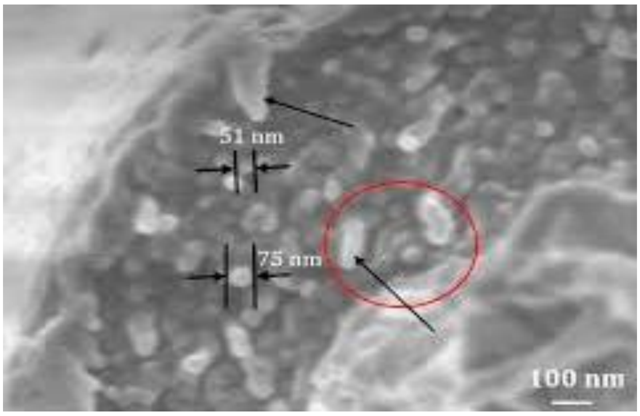
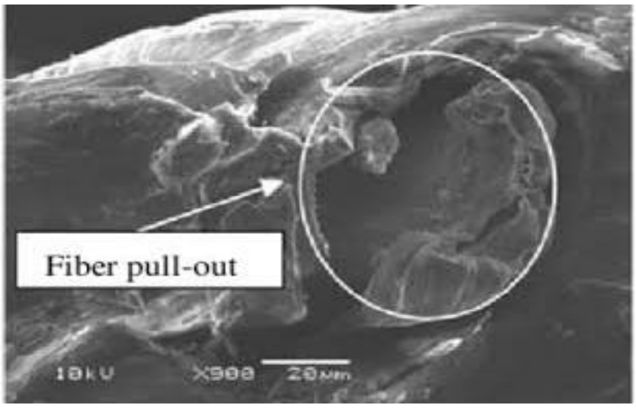


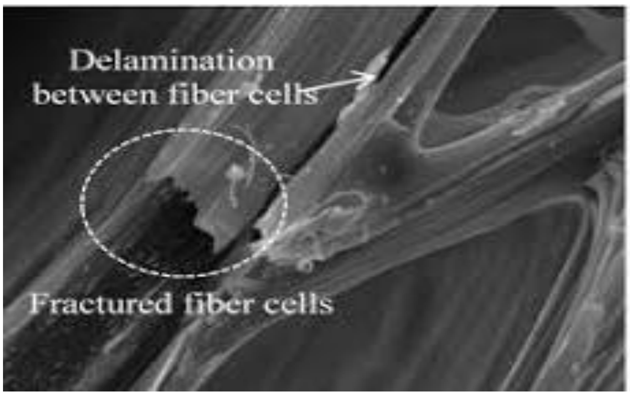
Figure 7: Stress vs strain curves of the specimen



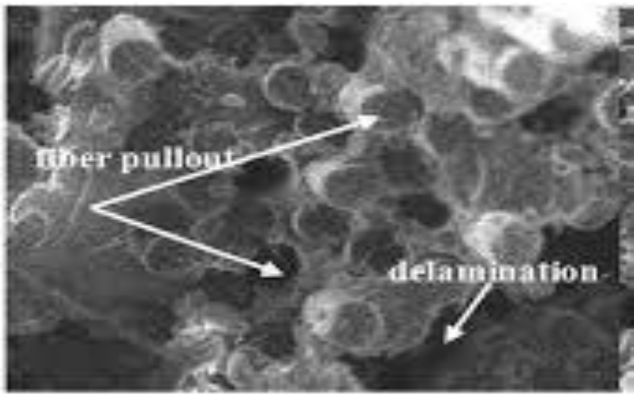
1.SEM IMAGE OF COMPOSITE ALG0



2.SEM IMAGE OF COMPOSITE ALG2



3.SEM IMAGE OF COMPOSITE ALG4



4.SEM IMAGE OF COMPOSITE ALG5

Figure 8: SEM images 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 Al_2O_3 Nanofiller have shown negative effect on their properties.

2. The inclusion of Al_2O_3 Nano particles to the epoxy will give adequate hardiness to the matrix there by giving good Impact strength for CRP- Al_2O_3 Nanocomposites.

3. It has found that 2wt% of Al_2O_3 Nano particle for ALG2 specimen showed enhancement in Mechanical properties compared to ALG3, ALG4 and ALG5.

REFERENCES

1. Synthesis and characterization of zinc oxide (ZnO) filled glass fiber reinforced polyester composites Nafisa Gulla, Shahzad Maqsood Khana, Muhammad Azeem Munawara, Muhammad Shafiqa,Farheen Anjuma, Muhammad Taqi Zahid Butt.Elesiver mateials and design 65(2015) 313-317. https://www.researchgate.net/publication/269777339_Synthesis_and_characterization_of_zinc_oxide_ZnO_filled_glass_fiber_reinforced_polyester_composites
2. Fabrication and Mechanical Characterization of Glass fibre reinforced Epoxy Hybrid Composites using Fly ash/Nano clay/Zinc oxide as filler. Susilendra Mutalikdesai1, Akshay Hadapad, Sachin Patole and Gururaj Hatti IOP science. https://iopscience.iop.org/article/10.1088/1757-899X/376/1/012061
3. Fabrication and Mechanical Characterization of Glass fibre reinforced Epoxy Hybrid Composites using Fly ash/ Nano clay/ Zinc oxide as filler. Susilendra Mutalikdesai1 , Akshay Hadapad2 , Sachin Patole3 , Gururaj Hatti. https://iopscience.iop.org/article/10.1088/1757-899X/376/1/012061/pdf.
4. Influence of Zinc Oxide and Silicon Carbide Micro fillers on Impact Strength and Hardness in E-Glass/ Polyester Composites: Fabrication and Testing. Reddy Sreenivasulu. https://www.akgec.ac.in/wp-content/uploads/2019/06/4-Influence-of-Zinc-Oxide-and-...-Reddy-Sreenivasulu.pdf
5. Erosive wear characteristics of E-glass fiber reinforced silica fume and zinc oxide-filled epoxy resin composites. Bülent Öztürk Hasan Gedikli Yavuz S. Kılıçarslan. **https://doi.org/10.1002/pc.25372**.
6. Influence of ZnO and SiC Micro Fillers on Mechanical Properties of E-Glass/Polyester Composites. B. Bhargavi1 , Reddy Srinivasulu.
7. Evaluation of Mechanical and Erosive wear Characteristics of TiO2 and ZnO Filled Bi-Directional E-glass Fiber Based Vinyl Ester Composites. Akant Kumar Singh ,Siddhartha, Prabhaker Gupta

8. Prashant Kumar Singh. https://link.springer.com/article/10.1007%2Fs12633-016-9447-3.
9. Review-Effect of Fillers on Mechanical Properties of Polymer Matrix Composites. Author links open overlay panel M.D.KiranaH.K.GovindarajuaT.Jayaraju, NithinKumar. https://www.sciencedirect.com/science/article/pii/S2214785318317449
10. Synthesis and characterization of zinc oxide (Z) filled glass fiber reinforced polyester composites
11. Strength Characterization of E-glass Fiber Reinforced Epoxy Composites with Filler Materials Mechanical, thermo-mechanical properties of epoxx/glass composites with submicron particles Gull, Nafisa; Khan, Shahzad Maqsood; Munawar, Muhammad Azeem; Shafiq, Muhammad; Anjum, Farheen. https://www.deepdyve.com/lp/elsevier/synthesis-and-characterization-of-zinc-oxide-zno-filled-glass-fiber-6FhO1qy76S.
12. Erosion wear behavior of oxide fillers reinforced epoxy composites: A Review. Anant K. Pun. https://www.elkjournals.com/microadmin/UploadFolder/3090paper%2022.pdf
13. Effect of Nanotechnology in Enhancing Mechanical Properties of Composite Materials 1 M.Ramachandran, Rishabh Bhargava, 2 Dr. P.P. Raichurkar. https://engineering-shirpur.nmims.edu/docs/10-effect-of-nanotechnology-in-enhancing-mechanical-properties-of-composite-materials.pdf
14. Enhanced mechanical properties of glass fibre-reinforced polymer composites with addition of AL2O3. Chidambaram, Gowri Sankar, adayan, Navaneethakrishnan V, Sivabharathi. https://www.tandfonline.com/doi/abs/10.1080/14484846.2019.1681848?journalCode=tmec20
15. comparitive study on mechanical and thermal behaviour of glass fiber reinforced epoxy based composites with Sic & Tio Jush Kumar Siddani , Dr. C. Srinivas , G. Moses Dayan. http://www.ijesrt.com/issues%20pdf%20file/Archive-2018/April-2018/62.pdf.
16. Strength Characterization of E-glass Fiber Reinforced Epoxy Composites with Filler Materials K. Devendra, T. Rangaswamy.
17. Effect of Strain Rate and Nano-ZnO Addition on Mechanical Properties of Glass Fiber Reinforced Polyester Composite. Samar E. Salem.
18. Stress-Strain Analysis and Deformation behaviour of fibre reinforced Styrene-Ethylene-Butylene-Styrene Polymer Hybrid Nanocomposites. Subramanian Ravichandran, E.Vengatesan, A.Ramakrishnan https://www.materialsciencejournal.org/vol16no1/stress-strain-analysis-and-deformation-behaviour-of-fibre-reinforced-styrene-ethylene-butylene-styrene-polymer-hybrid-nanocomposites/
19. Synthesis and prediction of surface morphology, physical and mechanical properties of functionalized nano zinc-oxide embedded in unidirectional S-glass fiber epoxy composites Karani Dileep Kumar https://www.frt.org/journal/frt/browse-the-journal/volume-2/synthesis-and-prediction-of-surface-morphology-physical-and-mechanical-properties-of-functionalized-nano-zinc-oxide-embedded-in-unidirectional-s-glass-fiber-epoxy-composites
20. Mechanical, thermo-mechanical properties of epoxx/glass composites with submicron particles. Marcin WŁOCH, Janusz DATTA. http://sdpg.pg.gda.pl/pij/files/2013/09/01_2013spec_17-wloch.pdf.
21. Mechanical Characteristics of Aluminium Powder Filled Glass Epoxy Composites. P. Sarkar et al., "Mechanical Characteristics of Aluminium Powder Filled Glass Epoxy Composites", International Journal of Engineering and Technologies, Vol. 12, pp. 1-14, 2017.

AUTHORS PROFILE

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

B. W. Sandeepkumar, Assistant professor Vemu Institute of Technology, Chitoor Dist, Andhrapradesh.