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Effect of Nanomaterials on Mechanical Properties in Fiber Reinforced Polymer Composite-A Review

Pranesh K G[1], Channabasavaraj S[2]

[1]*Assistant Professor, Dept. of Mechanical Engineering, Acharya Institute of Technology, Bengaluru, Karnataka, India*
[2]*Professor and Head, Dept. of Mechanical Engineering, R R Institute of Technology, Bengaluru, Karnataka, India*

Abstract – *This paper reviews on the addition of nanomaterial with matrix material used in the manufacturing process of fiber reinforced polymer composite (FRP) materials. The composite materials are the alternative to conventional materials used in the manufacturing process of various components due their good weight to strength ratio and mechanical properties like tensile strength, flexural strength, interlaminar shear strength, compressive strength, impact strength and hardness. These properties can be further enhanced with the addition of nanomaterials like, nanosilica, aluminum oxide, titanium oxide, carbon nanotubes, nanoclay, calcium carbonate, graphite, molybdenum di sulphide in a small quantity to the matrix material like epoxy, vinyl ester, polyester, polyethylene during the composite manufacturing methods like hand layup, vacuum bagging, vacuum assisted resin infusion method*.

Key Words: **Composite, mechanical properties, Nanomaterial, matrix material, composite manufacturing**

1. INTRODUCTION

Composite materials play vital role in the present mechanical industry as an alternative material to the conventional due their good weight to strength ratio and also enhanced mechanical properties compared to conventional materials. Presently the mechanical industries are focusing on reducing the weight of the components without compromising the strength, as a result there is lot of scope in the field of composite materials. Composite materials have two or more materials with significantly different properties in a microscopic level. The base material in the composite is matrix and constituent which is added to the matrix is known as reinforcement material. Now the composites along with these matrix and reinforcement, fillers are also added. Composite materials may be classified based on fiber and matrix. The fiber based composites are particulate composites, fiber composites and laminate composites. Based on matrix, metal matrix composites, ceramic matrix composites and polymer matrix composites. Mechanical properties of composite materials can be enhanced by adding a small quantity of nanomaterial or nano fillers to matrix material during composite manufacturing. Matrix materials used in manufacturing of composite are epoxy, vinylester and polyester resins. Epoxy is one of the most common matrix material used in the manufacturing of composites because it has good mechanical properties, good adhesive strength, chemical and solvent resistant, low shrinkage and moisture resistant compare to other matrix materials. Composite find applications in automotive, aerospace, spacecraft, sports, marine, electrical and medical.

1.1 Nano Composites

Presently the research work in the field of composite material is driven by nanocomposites. Nanocomposite is a composite of two materials in which one of the material in nano size. In order to enhance the mechanical and other properties of conventional composite materials, the researchers are conducting the more research work by adding the nanomaterial to the matrix material. The major challenges in the addition of nanomaterial to the matrix material involve uniform mixing of nanomaterial with matrix and viscosity of matrix increases with the addition of nanomaterial.

1.2 Nanomaterials

Nanomaterials having particles of nanoscale dimensions ranging from 1 to 100 nanometre. Nanomaterials may be in the form of zero dimensional, one dimensional and two dimensional. The most commonly zero dimensional nanomaterial are nanoparticles, one dimensional material includes nanorods, nanotubes, and nanowires, two dimensional materials include nanofilms, nanolayers, and nanocoatings. Nanomaterials may be classified based on carbon, metal, dendrimers and composites. The zero dimensional nanomaterials with polymer matrix possess good mechanical and thermal properties. The nanotubes or nanorods with composites used for reinforcement or to introduce electric conductivity to the polymer. Some of the commercially available nanomaterials are nanosilica, aluminium oxide, titanium oxide, silicon carbide, graphene, carbon nanofibers, and multiwall carbon nanotubes and many more. Presently nanomaterials are extensively used in manufacturing the nanocomposite components for automotive, aerospace, space crafts and marine applications.

2. Manufacturing of Fiber Reinforced Polymer composites

The fiber reinforced polymer composite (FRP) materials are manufactured using different methods like hand layup, vacuum bagging, vacuum assisted resin infusion method, Autoclave. Liquid composite moulding and compression moulding. Most of the research works were done using hand layup method. The percentage of mechanical properties enhances also depends on the nano composite fabrication methods.

3. Effect of Nanomaterial on Mechanical properties in Fiber Reinforced Polymer composites

Sushil Kumar Singh et.al [1]: In this paper researchers focused on the effect of nano $SiO_2$with epoxy on tensile and flexural properties. The nano SiO_2 added with epoxy in different weight percentage like 0,2,4,6 and 8. Composites were manufactured using handlayup method. The specimens were tested for tensile and flexural strength. The addition of nano SiO_2 with epoxy up to 4 weight percentage gives better result as compared to pure epoxy later it starts decreases due agglomeration. The tensile strength increases up to 30.57%, flexural strength increases upto 17% and flexural modulus increases upto 76% as compare to pure epoxy.

Ramesh K Nayak et.al [2]: Studied the effect of epoxy matrix modifier using Nanomaterials like Al_2O_3, SiO_2 and TiO_2 10wt% in glass fiber/epoxy composite on improvement in the mechanical properties. The composites was manufactured by handlayup process and tested for flexural strength, flexural modulus, ILSS, Hardness and Impact energy. The results revealed that the flexural strength, flexural modulus, ILSS, were more in case of SiO_2 modified epoxy composites compare to other modifiers and also the hardness and impact energy was observed more in case of Al_2O_3 modified epoxy composite as compare to other modifiers.

Krishan Kumar Patel et.al [3]: Research work studied on development and characterization of thermosetting epoxy polymer with nano SiO_2 ranging from 1 to 4 weight percentage. The test specimens were tested for tensile, flexural, hardness and impact strength. These test result shows that 3 wt% addition of nano SiO_2 gives better result compared to 1 and 2 weight percentage but more than 3 weight percentage these results starts decreasing due agglomeration.

Ahmed A. Moosa et.al [4]: Research work concentrated on the preparation of silica nanoparticles from rice husk ash. The silica nanoparticles were mixed with epoxy resin in different weight percentages like 0, 0.25, 0.5, 0.75, 1, 2, 3, 6, 9, 12 and 14. The specimens were tested for tensile strength. The result after the test revealed that best tensile strength found at 0.5 weight percentage compare to other weight percentage. After 0.5 weight percentage, the tensile strength starts decreasing due to agglomeration.

Omer Yavuz Bozkurt et.al [5]: Researcher studied on the effect of addition of nanosilica with glass/epoxy fiber on tensile and flexural characteristics. The nanosilica added in four different weight percentages with epoxy like 1, 1.5, 2 and 3. The laminates were fabricated using hand layup method. The specimens were tested on tensile and flexural strength. The result shows that the tensile strength increase with the addition of nanosilica up to 2 weight percent as compare to pure specimens, after 2 weight percent the tensile strength starts decreasing due to agglomeration. The flexural strength and flexural modulus shows better result at 1.5 weight percent of nanosilica added with the epoxy compare to other weight percentage, after 1.5 weight percentage the results starts decreasing due to agglomeration of nanoparticles in the matrix.

Gurkirat Singh et.al [6]: The researchers investigate the effect of addition of silicon dioxide filler in different weight percentage with vinylester and aramid fiber composites. The silicon dioxide filler added in different weight percentages like 0, 5, 10, 20 and 30. The laminates fabricated using hand layup process and specimens were tested for hardness, tensile and flexural strength. The result shows that adding silicon dioxide filler provides an increasing in the result as compare to pure specimens and good results found at 20 weight percentage, adding more than 20 weight percentage of silicon dioxide filler results decrease in hardness, tensile and flexural strength.

Suresh.J.S et.al [7]: Experimentation was carried out to find the effect of filler materials like titanium oxide and silicon carbide with glass/epoxy fiber reinforced polymer composites. The filler materials were added in different weight percentages like 0, 5 and 10. Composites were manufactured using hand layup. The specimens were tested to investigate the effect of filler materials on tensile strength, flexural strength, impact strength and hardness as per ASTM standards. The results shows that adding filler materials increases the tensile strength, flexural strength, impact strength and hardness values as compare to pure specimens. 5 weight percentage of filler materials provides better results, after 5 weight percentage the results starts decreasing in tensile strength, flexural strength and impact strength. 5 weight percentage of silicon carbide provides highest flexural strength as compared to other filler composites due to increased adhesive strength between matrix and fiber. However the hardness values were increased as compare to pure specimens in 5 and 10 weight percentages, more over highest hardness value find at 10 weight percentage. The increase in hardness value may be the incorporation of brittle fibers in the epoxy resin.

M. Fathalian et.al [8]: Investigation work carried out by the researchers on the influence of nanosilica in different weight percentages like 0.1, 0.3, 0.6 and 1.0 with carbon fiber/ Polycarbonate laminates. The specimens were tested for tensile strength. The 0.6 weight percentage gave highest result in tensile modulus and yield stress as compare to other weight percentages. These results starts increasing by adding nanosilica as compare to pure specimens but after 0.6 weight percentage tensile modulus and yield stress starts decreasing.

Hasan Yavuz Unal et.al [9]: The researchers focused on the study of effect on addition of nanoclay with glass/carbon/glass fiber reinforced epoxy matrix. The nanoclay was added in different weight percentages like 0, 0.75 and 1.25 with the epoxy matrix. The laminates were prepared by hand layup method. The specimens were prepared as per ASTM standards for tensile and flexural loading. The tensile tested specimens shows that there is an increase in tensile strength and break strain in nanoclay added specimens when compare with pure specimen, however the young's modulus decreased in nanoclay added specimens when compared with pure specimen. The highest tensile strength found at 0.75 weight percentage of nanoclay added specimen and 4 % more than the pure specimen, but in 1.25 weight percentage of nanoclay specimen the tensile strength decreased as compare to 0.75 weight percentage of nanoclay but when compare to pure specimen the strength more. The highest break strain found in the specimen having 1.25 weight percentage of nanoclay and 5 % more than pure specimen. The flexural strength and modulus increased with the addition of nanoclay as compare to pure specimen. The flexural strength increased by 4% and 12% in 0.75 and 1.25 weight percentages nanoclay composites as compared with pure specimen. The highest flexural modulus observed in 1.25 weight percentage nanoclay composite as compare to pure specimen by 5%. Break strain increased in nanoclay composite specimen as compare to pure specimen and highest at 1.25 weight percentage. The glass transition temperature decreased in nanoclay added specimens as compare to pure specimen.

Madeha Jabbara et.al [10]: The objectives of researchers to determine the effect of silica nanofiller on mechanical properties of Kevlar/Epoxy composite. The nanofiller added with epoxy by volume percentages like 4, 5, 12 and 16. The Specimens were tested for tensile, flexural and impact strength. The tested specimens revealed that the above mechanical properties shows an increased values up to 8%, due to interfacial adhesion, further addition of nano materials starts decreasing trend and also with the addition of nano materials the failure behavior of the material changes from ductile to brittle.

Y. Asha Ravalika et.al [11]: The research work evaluated the tensile properties of nanosilica reinforced with Kevlar/sisal fiber with polyester resin hybrid composite. The laminate were prepared in different fiber stacking sequence like Kevlar/sisal/Kevlar/sisal, sisal/Kevlar/Kevlar/sisal and Kevlar/sisal/sisal/Kevlar with the addition of nanosilica in different weight percentages like 1, 2 and 3. The tested specimen shows that addition of nanosilica increases the tensile properties up 2 weight percentage later on it starts decreasing. The highest tensile strength observed in fiber stacking sequence Kevlar/sisal/sisal/Kevlar with 2 weight percentage of nanosilica and maximum tensile modulus in sisal/Kevlar/Kevlar/sisal at 2 weight percentage of nano silica.

Muhammad E Hossain et.al [12]: Here the research work focused of investigation of low velocity impact behavior of carbon nano fiber filled E-glass reinforced polyester composite with E-glass/polyester composite. The carbon nano fiber added with matrix material with different weight percentages like 0.1, 0.2 and 0.3. The composite were fabricated using vacuum assisted resin transfer molding process and the sample size as per ASTM D3763. Low velocity impact loading were carried out at different energy levels like 10J, 20J and 30J for both conventional and nano filled composites using Dynatup8210. After the test the results shows that peak load increased with the increasing impact energy. The peak load observed more in nano filled composites as compare with conventional one and also the absorbed energy decreases when the nano material added, The 0.2 weight percentage carbon nano fiber filled E-glass reinforced polyester composite shows highest peak load and lowest absorbed energy as compare with conventional one.

Asmaa S. Khalil et.al [13]: Here the researchers investigate the effect of silicon dioxide nano material on flexural properties and hardness of the composites. The composites were prepared with distinctive weight percentage of silicon dioxide nanomaterial like 1, 2, 3 and 4 with epoxy/multi wall carbon nano tube. Here the researchers maintain a constant 3 weight percentage of multi wall carbon nano tube in all composites. The test result shows that the addition of nano materials with epoxy increases the flexural strength and hardness as compared to pure epoxy. The highest flexural strength observed at 2 weight percentage of silicon dioxide, later on it starts decreasing due to agglomeration but more than the pure specimen. The hardness increases as the addition of silicon dioxide nanomaterial, the maximum hardness found at 5 weight percentage of silicon dioxide nanomaterial which about 17% as compare to pure specimen.

Omer Faruk Erkendirci et.al [14]: The researchers studied the effect of nanomaterials on mechanical properties of different composite material laminates. The two different nanomaterials used in this study were carbon nano tube(CNT) and silica (SiO_2). These nanomaterials were added with epoxy resin in 0.3 weight percentage of CNT and 4 weight percentage of SiO2 in four different combinations like SiO_2, CNT, SiO_2+CNT and none. The hybrid nano composite were prepared with plain weave carbon/glass fiber fabric with nanomaterial added epoxy. The composites were prepared in different thickness by varying the number of layers of fabric like three, five, seven, eleven and fifteen. The composites were fabricated with VARTM (Vacuum Assisted Transfer Mol) process. The tested specimen results conclude that by adding nanomaterials the mechanical properties were affected. The increase in tensile strength were observed in nanocomposite as compare to pure one

4. Conclusion

Today in the composite material world the researchers are focusing to enhance the mechanical properties of conventional composite materials by adding a very small weight or volume percentage of nanomaterial to matrix materials. The literature survey revealed that a desired quantity of nanomaterial enhance the mechanical properties on the other side by adding more percentage of nanomaterial the mechanical properties starts decreasing due to agglomeration.

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