

Impact and Flexural Behavior of Glass Fiber Reinforced epoxy Clay Nano Composite

Dr. P. L. Srinivasa Murthy¹, Amit Kashyap², Dr.B.N.Sarada³, K. Sarvesh⁴

^{1, 2, 3, 4} Dept of Mechanical Engineering

^{1, 2, 4} Ramaiah Institute of Technology, Bangalore, Karnataka, India

³BMS College of Engineering, Bangalore, Karnataka, India

Abstract- Nano composites have gained significant attention in the recent past because of their superior strength while maintaining weights lesser than commonly used metals. In this publication, laminates of Glass Reinforced Plastic (GRP) based on epoxy (diglycidyl ether of bisphenol A and a hydride curing agent) and nano clay reinforcement (Montmorillonite) were synthesized using vacuum bagging technique. Upon flexural testing of the laminates, it can be observed that there is an improvement in strength when adding >1% wt. of reinforcement. Although linear improvement in impact strength is obtained with increase in reinforcement, there can be seen a critical composition with 3% wt. reinforcement where there is a sharp decrease in the otherwise increasing tensile strength, when compared to the pure matrix specimens. The reported results provide a guidance on how to optimize the composition of the composite depending on the application such as in boat hulls, body of an automotive vehicle, etc.

Keywords- Flexural strength, Impact strength, Laminate Nanocomposites, Tensile strength, Vacuum bagging technique.

I. INTRODUCTION

Among the class of composite materials, nanocomposites are multiphase solids which require filler materials, needed to be in the order of a nanometer, specifically in the range between 1 to 100 nm. The works on polymer/inorganic nano composites which are underway have shown significant enhancements in stiffness, strength and thermal properties over those of polymers without compromising on material density and toughness [11]. With the use of organic and inorganic fillers becoming very common in polymeric systems, the focus on the development of polymeric nanocomposites has seen a substantial increase in the past 20 years [8,10]. The manufactured product obtained need not have to be in nano scale, products in micro-macroscopic sizes can also be achieved. This can be characterized by the usage of Scanning Electron Microscopes and Transition Electron Microscopes. Such polymer composites are being manufactured in abundance and have gained commercial viability for various applications in

aerospace components, automobiles, sports goods, etc.

A. Epoxy Resin

The term ‘epoxy resin’ refers to both the pre-polymer and its cured resin/hardener system. The former is a low molecular weight oligomer that contains one or more epoxy groups per molecule (more than one unit per molecule is required if the resultant material is to be crosslinked). The characteristic group, a three-member ring known as the epoxy, epoxide, oxirane, glycidyl or ethoxy line group, is highly strained and therefore it is very effective. Epoxy resins can be cross-linked through a polymerization reaction with a hardener at room temperature or at elevated temperatures (latent reaction).

Curing agents used for room temperature are usually aliphatic amines, and for high temperature, aromatic amines and acid anhydrides are used. Polyfunctional amines, polybasic carboxylic acids, mercaptans and inorganic hardeners are also used as specialized curing. In general, the high temperature cured resin systems have improved properties, such as higher glass transition temperature, strength and stiffness, compared to those cured at room temperature.

B. Clay

Clays are hydrous silicates or alumino silicates and they fundamentally contain silicon, aluminum or magnesium, oxygen and hydroxyl with various associated cations. These ions and OH groups are organized into two dimensional structures as sheets. Clay minerals are also known as layered silicates or phyllo silicates because of their structural frame work which are basically composed of silicate layers with a thickness of 1nm, comprising of silica and alumina sheets that are joined together in various proportions and stacked on top of each other in a certain way with variable interlayer distance.

C. Montmorillonite

Among the various types of clays available, montmorillonite is one of the most popular and commonly used clays which are used for the preparation of epoxy-clay nano composites. Because of its peculiar structure as shown in the fig-1, montmorillonite has the ability to show interlayer expansion and swelling. The crystal structure of montmorillonite consists of layers formed by sandwiching an edge shared octahedral sheet of alumina between two silica tetrahedral sheets, so that the apical oxygen atoms of the tetrahedral sheets are all shared with the octahedral sheet. Isomorphs substitution of aluminum for silicon in the tetrahedral sheet and iron or magnesium for aluminum in the octahedral sheet provides an overall negative charge to the crystal lattice. As the surface between the layers is negatively charged it attracts cations such as Fe^{2+} , Ca^{2+} or Na^+ . They form a positively charged layer between the negatively charged surfaces of the clay layers. Such layers extend continuously in the plane constituted by the x and y axes and are stacked up in the z axis, forming the whole crystal structure. The silicate layers of MMT are planar, stiff about 1 nm in thickness with high aspect ratio and large active surface area (700–800 m²/g). These layers organize themselves in a parallel manner to form stacks, with a regular Van der Waals gap in between them, called as interlayer or gallery. The sum of the single layer thickness and the interlayer is called spacing or basal spacing. The total quantity of the absorbed cations (K^+ , Na^+ , Ca^{2+} , and Mg^{2+}) in the inter gallery of clay layers at a PH value of 7 is referred to as the cation exchange capacity (CEC) of clay minerals. It is measured by the unit mill mol/100g of layered silicate (or MMT). Higher the value of negative charge, the stronger is the capacity for hydration, swelling and dispersion.

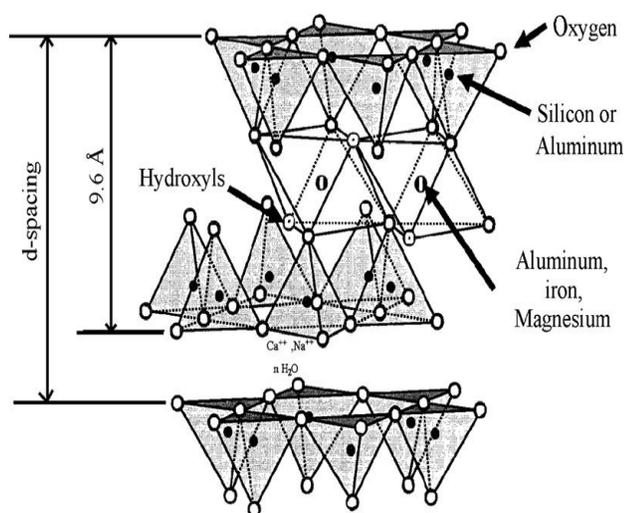


Fig 1: Structure of Montmorillonite

D. Epoxy clay nanocomposite

The processing of the epoxy based nanocomposite is easy in manufacturing and has versatile application in different fields, therefore the properties and structure of epoxy clay nanocomposite is influenced by the curing agent, the type of clay modifiers and the processing method [7].

II. EXPERIMENTAL

A. Material

The Montmorillonite nano clay of aluminosilicate layer of 1nm thick plate like stakes multilayered with stake size of 5-10 micro meter, specific gravity 2.6 and PH of 9.5-10.5 and a powder white in color is used in this study. Araldite LY 556 based on diglycidyl ether of bisphenol A, araldite HY925, and a hydride based curing agent is used in this study. The glass fiber reinforced polymer used for the fabrication is of bidirectional mat having 300gsm.

B. Preparation of the epoxy-layered silicate nanocomposite

A selected amount of LY556 resin was heated up to certain temperature in a container. Then montmorillonite clay is added to the resin corresponding to 10 wt% of the epoxy system



(LY556+ HYp25) to the DGEBA resin and mixture was sonicated in the sonicator to get good dispersion of the clay in the resin for about an hour and then it is taken out for the preparation of the laminates.

C. Preparation of the Glass Fiber-Reinforced Laminates

Following the procedure [2,4], ten plies (300mm*300mm) were cut from the glass fiber mat with sharp scissors. A thin layer of epoxy or epoxy/ nano clay mixture was applied with a brush on the plane surface which is cleaned by acetone to remove dust and after a minute, releasing agent

such as wax is applied on the surface. Followed by this, the first ply was laminated, until it became completely wet with resin. Additional resin was added and the second ply was laminated for complete wetting. This procedure was repeated until all the plies were superimposed. It was then covered with a peel ply, a perforated film, and a breather fabric which is then introduced in a vacuum bag. An inlet and an outlet placed on the vacuum bag were then sealed with a sealant tape. Vacuum was created in the bag and a pressure of 2 bar was applied followed by the curing of laminate for 2 hours. The laminate was then removed from the vacuum bag and post-cured for 1 hour at 100°C. Procedure is repeated to manufacture 4 laminates for 1%, 3% and 5% of clay with epoxy.

D. Tensile Test

A Universal Testing Machine was used to measure the tensile strength of the GRP specimens. These test specimens were prepared as per ASTM D-3039 standard and were tested for failure to know the peak load and ultimate stress value.



Fig 2: Vacuum Bag Method



Fig3: Laminates of 0%, 1%, 3%, 5% Clay of NanoComposite

E. Flexural Test

Three-point bending tests of specimens were carried out using Zwick / Roell. The test specimens were prepared according to ASTM-D-790 standard.

F. Drop Impact Test

The drop weight impact test was conducted using an instrument Instron Dynatup 9250G machine fitted with a hemispherical top of 12.5 mm diameter. The load cell was calibrated for each test and impacts were performed on an exposed area of 110 x 110 mm while the four sides were in a clamped position. Four energy levels, i.e 10, 20, 35 and 50 J were selected, based on the damage types, while the concentration of Nano clays dispersed were 0%, 1%, 3% and 5%. A total of four samples were tested.

III. RESULTS AND DISCUSSION

A. Flexural Test

The results obtained by conducting three-point flexural tests on nanocomposites using Zwick/Roell universal testing machine are shown below in the table. Addition of different nanoclays has resulted in improvement of flexural strength. Maximum of them showed widening at 5 % nanoclay loading. There was an enhancement in flexural strength which was obtained at 5% nano clay in comparison to neat epoxy glass fiber specimens, as observed in other literature [5]. Also, the gap between flexural strength of clay and neat epoxy showed widening at 5% nanoclay loading.

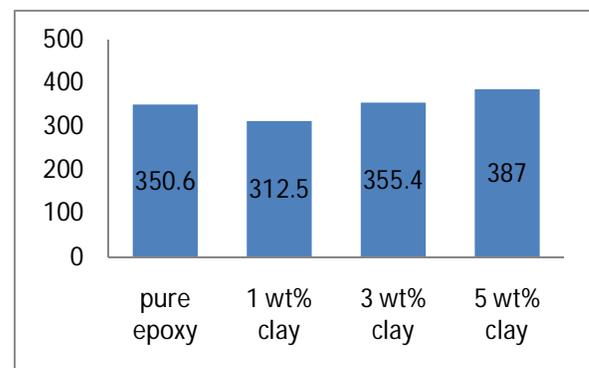


Fig4: Flexural Strength vs % of Clay

B. Tensile Test

It is observed that the tensile strength of nanocomposite increased with increasing concentration of nanoclay. The improvement in tensile strength can be attributed to the good dispersion of the nano size clay particles [6,9]. The graph indicates the changes in tensile strength with clay content. But at 3%wt of clay there is decrease in strength due to bad dispersion of clay as per the work carried out.

C. Drop Impact Test

It can be observed from figure that the samples with 1%wt nano clay loading absorbed less energy as compared to 3%wt and 5%wt clay samples. In general for this study the addition of clay decreases the energy absorption capability of the laminates, which may be due to increase in inter laminar shear strength. Less energy absorption is desired for the use of such laminates as the amount of damage is proportional to the amount of energy absorbed and therefore less internal damage will have a substantial effect on service life, reported an increase in absorbed energy with an increase in observed damage [1,3].

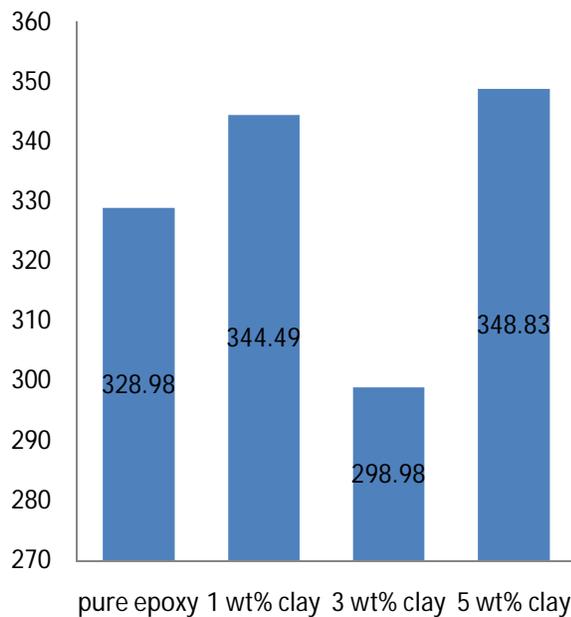


Fig5: Tensile Strength vs % of Clay

IV. CONCLUSION

- In this work the E glass fiber reinforced epoxy-nano clay composite are manufactured using vacuum bagging method.
- Addition of nano clay resulted in improvement in mechanical properties of fiber reinforced composites (flexural

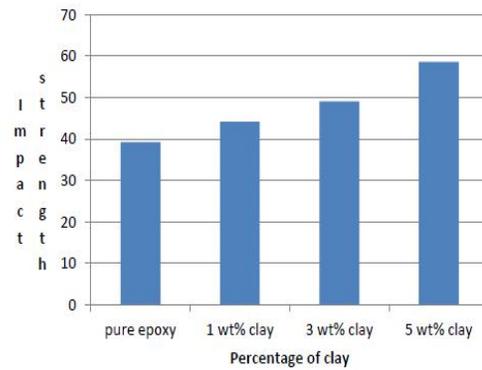


Fig6: Impact Strength vs % of Clay

strength, tensile strength and drop impact test).

- The apparent lower or no enhancement in tensile strength of glass fiber reinforced nanocomposite over glass fiber reinforced composite can be attributed to clustering of nano clay or to occasional occurrence of micro size voids in microstructure, especially at the interphase of nano clay and matrix.
- With better dispersion of the nano clay in epoxy, it is expected that there would be sufficient improvement in the tensile properties [10]. However, further investigations maybe required.

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