EFFECT OF NANO-ADDITIVES ON EPOXY COMPOSITES

A Thesis Submitted to

National Institute of Technology

Rourkela

In Partial fulfillment of the requirement for the degree of

Bachelor of Technology

in

Ceramic Engineering

By

GAURAV MISRA

110CR0613

Department of Ceramic Engineering

National Institute of Technology

Rourkela -769 008 (India)

2014

EFFECT OF NANO-ADDITIVES ON EPOXY COMPOSITES

A Thesis Submitted to

National Institute of Technology

Rourkela

In Partial fulfillment of the requirement for the degree of

Bachelor of Technology

in

Ceramic Engineering

By

GAURAV MISRA

110CR0613

Under the guidance and supervision of

Prof. S. K. PAL

Department of Ceramic Engineering

National Institute of Technology

2014

National Institute of Technology

Rourkela

CERTIFICATE

This is to certify that the thesis entitled "**Effect of nano-aditives on epoxy composites**" submitted to the National Institute of Technology, Rourkela (Deemed University) by **GAURAV MISRA**, Roll No. **110CR0613** for the award of the Degree of **Bachelor of Technology** in Ceramic Engineering is a record of bonafide research work carried out by him under my supervision and guidance. The results presented in this thesis has not been, to the best of my knowledge, submitted to any other University or Institute for the award of any degree or diploma.

The thesis, in my opinion, has reached the standards fulfilling the requirement for the award of the degree of **Bachelor of technology** in accordance with regulations of the Institute.

Date : 12/5/14

Prof. S. K. PAL
Assistant Professor
Department of Ceramic Engineering
National Institute of Technology, Rourkela
Rourkela

ACKNOWLEDGEMENT

I would like to express my profound gratitude and indebtedness to **Dr. S. K. Pal**, Assistant Professor, Department of Ceramic Engineering, NIT, Rourkela for his guidance and valuable suggestions. This work would not have been possible without his encouragement and constructive criticism. I sincerely thank him for the time and patience he devoted for this work.

I am also sincerely thankful to **Dr. S.K.Pratihar**, Head of the Department of Ceramic Engineering, National Institute of Technology, Rourkela for the allotment of this project and also for his continuous encouragement.

I am also thankful to **Dr. Raghavendra Gujjala**, Department of Mechanical Engineering, NIT Rourkela for his support & help during my experimental work.

Date : 12/05/14

Gaurav Misra

GAURAV MISRA

Department of Ceramic Engineering

National Institute of Technology, Rourkela

Abstract

Nanoparticle incorporation is a convenient way to enhance the mechanical properties of polymer matrices. In the last number of years abundant research has been done published concerning the enhancement of the mechanical properties of nanoparticle filled polymers. This work analyses the influence of nano clay and nano carbon reinforcement on the behavior of epoxy matrices. The nanoparticles were dispersed into the epoxy resin using a direct mixing method. Specimen preparation and testing were carried out as per ASTM standards. The investigation reveals that, due to incorporation of nano additives in epoxy composite to some extent give encouraging results when compared with the neat epoxy. After a certain amount of addition of additives these properties do not get enhanced and in some cases on further addition of additives the properties get depleted/deteriorated.

Keywords: Nanoparticles, epoxy composite, direct mixing method

Table of Contents

LIST OF FIGURES

LIST OF TABLES

CHAPTER-1

Introduction

1. INTRODUCTION :

Polymer composite materials have generated wide interest in various engineering fields, particularly in aerospace applications, because these materials exhibit high specific strength and stiffness as compared to monolithic metal alloy [6]. Due to the ease of fabrication and low cost, polymer composite materials find different application such as helicopter rotor blades, pipe line carrying sand slurries in petroleum refining, pump impeller blades[7,8], high-speed vehicles and aircraft operating in desert environments, water turbines, and aircraft engine blades.[9]

Natural fiber materials are dime a dozen in nature. Researchers are still working in this field to achieve composite materials with unique properties with low cost and environment friendly. For advanced composite matrix, thermosetting polymer i.e. epoxy resin is widely used for its good stiffness, dimensional stability and chemical resistance characteristic [10]. Natural lingo-cellulosic fillers (bamboo, flax, jute, hemp, etc.) are environmentally friendly in nature as compared to conventional reinforcing fibers (glass, carbon).[11,12] Luo and Netravali[13] studied the tensile and flexural properties of the green composites with different pineapple fiber content and compared with the virgin resin. Belmares [14] found that sisal, henequen, and palm fiber have very similar physical, chemical, and tensile properties.

1.1 DEFINITION OF COMPOSITE:

The most widely used meaning is the following one, which has been stated by Jartiz [2] "Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form". Accordingly one may classify among the composite materials nearly all substances such as bones, wood, shell etc., and also some man-made materials such as certain powder metallurgy products, electrical insulators, resin bonded magnetic materials, powder charged plastics, paper laminates etc..

The weakness of this definition resided in the fact that it allows one to classify among the composites any mixture of materials without indicating either its specificity or the laws which should give it which distinguishes it from other very banal, meaningless mixtures.

Kelly [3] very clearly stresses that the composites should not be regarded simple as a combination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them.

Berghezan [4] defines as “The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings”, in order to obtain improved materials.

1.2 Classification

Composite materials can be classified in different ways [5].

1.2.1 Classification based on reinforcing material

Particulate Composites

The reinforcement is of particle nature (platelets are also included in this class). In this type of composites, 1µm to 200µm size particles are dispersed in the matrix. It may be spherical, cubic, tetragonal, a platelet, or of other regular or irregular shape, but they are equiaxed. Generally particles are not very effective in improving fracture resistance but they enhance the stiffness of the composite to a limited extent. Particle fillers are extensively used to improve the properties of matrix materials such as to modify the thermal and electrical conductivities, improve performance at elevated temperatures, increase wear, reduce friction and abrasion resistance, improve machinability, increase surface hardness and reduce shrinkage.

Fibrous composites

A fiber is characterized by its length being much greater than its dimension of cross section. The dimensions of the reinforcement determine its capability of its properties to the composite. Fibers play very effective role in improving the fracture resistance of the matrix since a reinforcement having a long dimension discourages the growth of incipient cracks normal to the reinforcement that might otherwise lead to ultimate failure, particularly with brittle matrix composites.

1.2.2 Classification based on matrix material

1) Metal matrix composites

Metal matrix composites possess better properties, when compared with organic matrices. These include (i) can retain their strength even at higher temperatures, (ii) higher transverse strength, (iii) better electrical and thermal conductivities,(iv) better erosion resistance etc. Major disadvantage of metal matrix composites is higher densities and low specific mechanical properties when compared to polymer matrix composites. Another notable difficulty is requirement of very high energy for fabrication.

2) Polymer matrix composites

A very large proportion of polymeric materials consisting of both thermosetting and thermoplastic, are used as matrix materials in the preparation composites. The resinous binders (polymer matrices) are selected taking fatigue resistance, adhesive strength, heat resistance, chemical and moisture resistance etc into account. The resin must have mechanical strength with that of the reinforcement. It should be easy to be employed in the fabrication process selected and also satisfy the service conditions. On the other hand, the resin matrix must have the capability of wetting and penetrating into the bundles of fibers which provide the reinforcement, replacing the dead air spaces with in and offering those physical characteristics capable of enhancing the performance of fibers.

3) Ceramic matrix composites

Ceramic fibers, such as alumina and SiC (Silicon Carbide) have better results in very high temperature applications, and also where the environment attack is a major problem. Since ceramics show poor properties in tension and shear, most of its applications as reinforcement are in the particulate form (e.g. zinc and calcium phosphate). Ceramic Matrix Composites (CMCs) used in very high temperature environments, these materials use a ceramic material as the matrix and reinforce it.

Composites as engineering materials normally characterized by

1. These are artificially made (thus, excluding natural material such as wood).
2. These consist of at least two different species with a well-defined interface.
3. Their properties are influenced by the volume percentage of ingredients.
4. These have at least one property not possessed by the individual constituents.

CHAPTER-2

Literature Survey

2. LITERATURE SURVEY :

Epoxy is the cured final result of epoxy resins, and an everyday name for the epoxide functional group. Epoxy is additionally a typical name for a kind of strong adhesive utilized for sticking things together and covering surfaces [15], regularly two resins that need to be combined before utilization.

Epoxy resins, otherwise called polyepoxides are a class of reactive prepolymers and polymers which hold epoxide groups. Epoxy resins may be responded (cross-connected) either with themselves through reactant homopolymerisation, or with an extensive variety of co-reactants including polyfunctional amines, acids (and acid anhydrides), phenols, alcohols, and thiols. These co-reactants are frequently alluded to as hardeners or curatives, and the cross-joining response is regularly alluded to as curing. Reaction of polyepoxides with themselves or with polyfunctional hardeners structures a thermosetting polymer, regularly with great mechanical properties and additionally high temperature and compound safety. Epoxy has an extensive variety of modern provisions, including metal coatings, use in electronic and electrical parts, high pressure electrical separators, fiber-strengthened plastic materials, and structural glues. Epoxy sap is utilized to tie gutta percha in some root waterway procedures [16].

J.a.m. Ferreira , L.p. Borrego , J.d.m. Costa, C. Capela [19] reported that fatigue quality diminished with the nanoclay joining into the matrix. Fatigue life of nanoclay filled composites was altogether lessened by the score impact and by the submersion in water.

Jeena Jose Karippal, H.n. Narasimha Murthy, K.s. Rai, M. Sreejith and M. Krishna [20] reported that mechanical properties, for example, tensile strength, Young's modulus, flexural quality, flexural modulus, interlaminar shear quality, and microhardness of the cross breed composites expanded with expansion in nanoclay stacking up to 5 wt%. Glass transition temperature expanded barely at 2 wt% nanoclay stacking and the same diminished for further incorporation of the filler. The tensile-fractured examples were considered to inspect the mode of disappointment utilizing filtering electron magnifying instrument

JAM Ferreira, PNB Reis, JDM Costa, and MOW Richardson [21] reported that the addition of nanoclays reduced static strength and increased the stiffness in both tension and bend loading. Filled composites exhibited tensile fatigue strengths 12% higher than unfilled matrices, but in three-point bending the fatigue strength of filled composites was lower. The filler used was an organoclay Cloisite 30B after applying an appropriate silane treatment and other proprietary chemicals to improve the dispersion and interface adhesion. Twelve ply laminates, all in the same direction, of woven bidirectional Kevlar 292, were prepared by hand lay-up, using an SR 1500 epoxy resin. The composite sheets were produced by a vacuum moulding process.

Andrea Dorigato, Stefano Morandi, and Alessandro Pegoretti [22] reported that the shaping of intercalated microstructures prompted significant changes of the thermal (glass transition temperature) and mechanical (fracture toughness) properties of the epoxy matrix. E-glass fiber/matrix interfacial shear quality was assessed by the single-fiber microdebonding system. The presentation of organo-changed clays prompted the arrangement of a stronger fiber-matrix interface, with an expansion of the interfacial shear quality of about 30%. Simultaneously, the assessment of the fiber/matrix contact edge uncovered an enhanced wettability when organo-adjusted clays were included.

Arun K. Subramaniyan and C.t. Sun [23] reported that a decrease in interlaminar fracture toughness (both mode I and mode II) was seen in the nanoclay strengthened fiber composites. Arrangement of nanoclay along the fiber pivot was discovered to be a conceivable explanation behind this diminishment. Mode I and mode II tests were led to measure the interlaminar fracture toughness of nanoclay strengthened composites.

S. Zainuddin, M.v. Hosur, Y. Zhou, Alfred T. Narteh, Ashok Kumar, S. Jeelani [18] reported that ideal upgrade in 2 wt.% doped framework in both thermal and mechanical properties when contrasted with the perfect framework. X-ray diffraction (XRD) and transmission electron microscopy (TEM) effects showed blended intercalation and shedding of clay platelets in 2 wt.% framework. Scanning electron micrographs (SEM) of 2 wt.% specimens demonstrated rougher fracture surface in correlation to slick epoxy tests. In view of the trial comes about, a non-straight harm model utilizing flexural modulus and Weibull parameters was built to portray the stress–strain relationship. These recreated strain–strain relationship facilitated well with the test comes about and demonstrate that the Weibull scale parameter, expanded though the Weibull shape parameter, stayed harsh with increasing clay content.

Shafi Ullah Khan, Arshad Munir, Rizwan Hussain, Jang-Kyo Kim [24] reported that the fuse of nanoclay into CFRP composites not just enhances the mechanical properties of the composite in static stacking, additionally the fatigue life for a given cyclic burden level and the leftover mechanical properties after a given time of cyclic fatigue. The relating fatigue harm zone is altogether lessened because of nanoclay. Nanoclay serves to stifle and postponement delamination harm development and inevitable disappointment by enhancing the fiber/matrix interfacial bond and through the structuring of nanoclay-induced dimples.

A.Haque, M. Shamsuzzoha, F. Hussain, and D.Dean [25] reported significant improvements in mechanical and thermal properties of conventional fiber reinforced composites with low loading of organo silicate nanoparticles. By dispersing 1% by weight nanosilicates, S2-glass/epoxy-clay nanocomposites attributed to almost 44, 24 and 23% improvement in interlaminar shear strength, flexural strength and fracture toughness in comparison to conventional S2-glass/epoxy composites. Similarly, the nanocomposites exhibit approximately 26 C higher decomposition temperatures than that of conventional composites. This improved properties of fiber reinforced polymer nanocomposites are achieved mostly due to increased interfacial surface areas, improved bond characteristics and intercalated/exfoliated morphology of the epoxy-clay nanocomposites. The TEM observations provide evidence of detailed morphology of the polymer layered-clay nanocomposites.

Jia-Lin Tsai and Ming-Daw Wu [26] reported the organoclay impact on the mechanical properties of glass/epoxy nanocomposites. To exhibit the organoclay impact, three separate loadings, 2.5, 5 and 7.5wt% of organoclay were scattered in the epoxy resin utilizing a mechanical blender took after by sonication. The relating glass/epoxy nanocomposites were ready by embeddings the organoclay epoxy mixture into the dry glass fiber through a vacuum hand lay-up methodology. Tensile tests uncovered that longitudinal elasticity diminishes as organoclay stacking increases; then again, transverse tensile strength increments with the increment of the organoclay. Besides, SEM perception on the transverse disappointment examples shows that the improved component is because of the enhanced interfacial holding between the fibers and the encompassing matrix changed by organoclay. The expanding propensity was likewise found in the transverse flexural quality of the nanocomposites. Then again, mode I fracture tests showed that with the expansion of the organoclay, the comparing fracture strength of the nanocomposites diminishes considerably. For the semi-isotropic glass/epoxy overlays, since the disappointment is commanded by fiber crack, the quality is not affected altogether by the organoclay.

CHAPTER 3

Experimental Work

3. EXPERIMENTAL WORK:

Aim:

To find the effect of nano-additives, here nanoclay and naocarbon are used as nano-additives on epoxy composite.

Principle Involved:

On addition of nano additives in epoxy composite mechanical properties to some extent get enhanced when compared with the neat epoxy. After a certain amount of addition of additives these properties do not get enhanced and in some cases on further addition of additives the properties get depleted/deteriorated.

Chemical ingredients used:

1. Epoxy Composite
2. Hardener
3. Silicon Spray
4. Pervex Sheet
5. Nanoclay
6. Nanoclay

3.1 Procedure:

a) Mold Preparation : The mold was prepared on wooden boards with help of beads. The shape of the mold was rectangular.

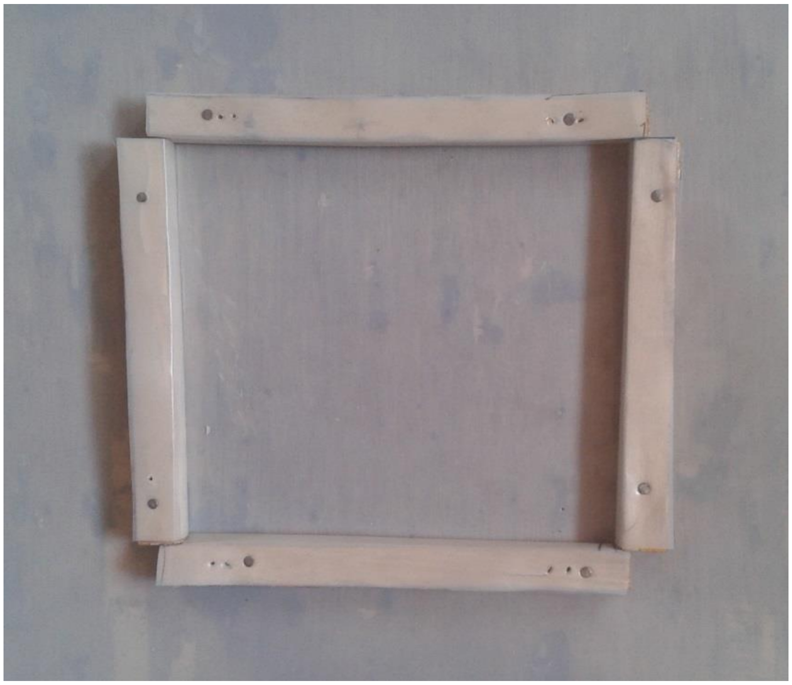


Fig. 3.1 Mold 1

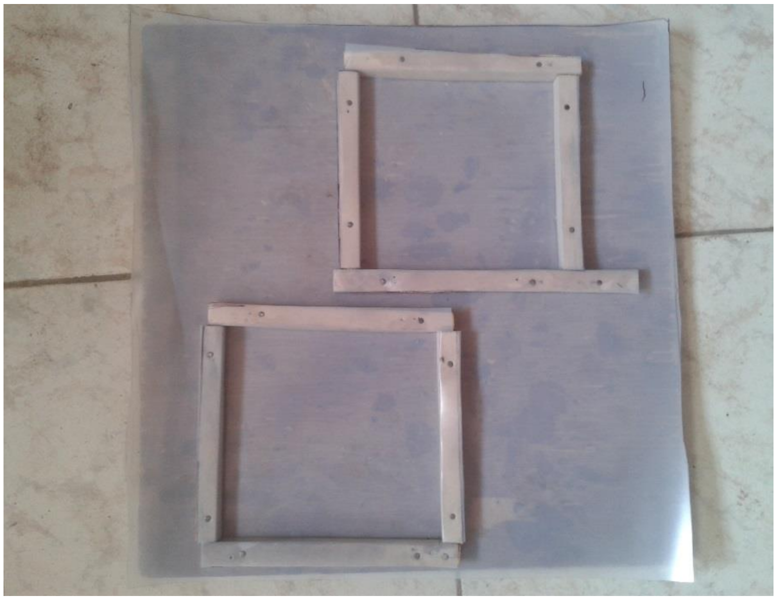


Fig. 3.2 Mold 2

Size of mold :

Breadth of the mold = 150mm

Length of the mold = 130mm

Height upto which the casting is to be done = 5mm

After mold preparation casting of neat epoxy is done first. The neat epoxy is mixed with hardener in 1:10 ratio then the mixture is poured into the mold and kept for 24 hours at room temperature under the application of weights so as to impart strength to the settled epoxy.

Volume of sample = Volume of composite (V_c) + Volume of nano- additive(V_a)

In case of neat epoxy sample, $V_a = 0$

$V_s = V_c$

V_s = 150mm*130mm*5mm

= 97500mm^3

= 97.5cm^3

Density of epoxy composite = 1.15gm/cm^3

Mass of epoxy composite poured into the mold1 sample = 1.15*97.5 = 112.25gm

Therefore, hardener required = 112.25/11= 10.21gm

Mass of neat epoxy used = (112.25-10.21)gm = 102.04gm

Hence, the mass of neat epoxy sample prepared has to be around 115gms.

After the preparation of neat epoxy samples, nanoclay reinforced matrixs are prepared.

3.2 Nanoclay reinforced epoxy composite samples preparation

Commercially available organoclay was used as the nanoclay which is reinforced into the epoxy matrix in the present work, density of this clay is 1.82gm/cm^3.

Density of nanoclay = 1.82gm/cm^3

3.2.1 2% nanoclay reinforced sample preparation :

2% of 97.5cm^3 = 1.95cm^3

Mass of nanoclay used = 1.82*1.95= 3.55gm

Mass of epoxy composite with hardener = (112.25-3.55)gm = 108.7gm

Mass of hardener used = 108.7/11 =9.88gm

Mass of neat epoxy used = (108.7-9.88)gm = 98.82gm

3.2.2 4% nanoclay reinforced sample preparation :

4% of 97.5cm^3 = 3.90cm^3

Mass of nanoclay used = 1.82*3.90= 7.10gm

Mass of epoxy composite with hardener = (112.25-7.10)gm = 105.15gm

Mass of hardener used = 105.15/11 = 9.56gm

Mass of neat epoxy used = (105.15-9.56)gm = 95.60gm

3.2.3 6% nanoclay reinforced sample preparation :

6% of 97.5cm^3 = 5.85cm^3

Mass of nanoclay used = 1.82*5.85= 10.65gm

Mass of epoxy composite with hardener = (112.25-7.10)gm = 101.6gm

Mass of hardener used = 101.6/11 = 9.23gm

Mass of neat epoxy used = (101.6-9.23)gm = 92.37gm

3.3 Nanocarbon reinforced epoxy composite samples preparation :-

Commercially available nanocarbon N115 was used as the nanocarbon which is reinforced into the epoxy matrix in the present work, density of this nanocarbon is 1.5gm/cm^3.

Density of nanocarbon = 1.5gm/cm^3

3.3.1 2% nanocarbon reinforced sample preparation :

2% of 97.5cm^3 = 1.95cm^3

Mass of nanoclay used = 1.5*1.95= 2.93gm

Mass of epoxy composite with hardener = (112.25-2.93)gm = 109.32gm

Mass of hardener used = 109.32/11 = 9.94gm

Mass of neat epoxy used = (109.32-9.94)gm = 99.38gm

3.3.2 4% nanocarbon reinforced sample preparation :

4% of 97.5cm^3 = 3.90cm^3

Mass of nanoclay used = 1.5*3.90= 5.85gm

Mass of epoxy composite with hardener = (112.25-5.85)gm = 106.40gm

Mass of hardener used = 106.4/11 = 9.67gm

Mass of neat epoxy used = (106.4-9.67)gm = 96.73gm

Plates with a dimension of 150 × 130 × 5 mm were moulded, from which the specimens were machined with the desired dimensions.

CHAPTER 4

Results and Discussion

4. **RESULTS AND DISCUSSION :**

The following tests were conducted on nanocomposite plates:

1) Density and void content
2) 3 point bending/Flexural test
3) Tensile test
4) Vicker’s hardness test

4.1 Density and void content calculation:

The density of composite materials in terms of volume fraction is found out from the following Eq (1 and 2).

$$\mathrm{s}_{\mathrm{ct}} = \frac{\mathrm{w}_0}{(\mathrm{w}_\mathrm{o}) + (\mathrm{w}_\mathrm{a} - w_b)} \qquad (1)$$

Where ‘‘S_{ct}’ represents specific gravity of the composite, w_0 represents the weight of the sample; w_a represents the weight of the bottle + kerosene, w_b represents the weight of the bottle + kerosene + sample,

$$\rho_{ca} = S_c \times \rho_k \qquad (2)$$

Where ρ_{ca} represents actual density of composite, ρ_k represents density of kerosene.

The theoretical density of composite materials in terms of weight fraction can easily be obtained as for the following Eq (3) given by Agarwal and Broutman [41].

$$\rho_{ct} = \frac{1}{\frac{w_f}{\rho_f} + \frac{w_m}{\rho_m}} \qquad (3)$$

Where W and ρ represent weight fraction and density. The suffix f, m and c stand for the fiber, matrix and the composite materials, respectively.

The void content of composite sample has been determined as per ASTM D-2734-70 standard procedure respectively. The volume fraction of voids (V_v) in the composites was calculated by using Eq (4).

$$V_v = \frac{\rho_{ct} - \rho_{ca}}{\rho_{ct}} \qquad (4)$$

Where ρ_{ct} and ρ_{ca} are the theoretical and actual density of composite respectively.

The actual density of the nanocomposite can also be calculated directly by using pycnometer. The principle involved in calculating the actual density by pycnometer is as follows :

First, we need to measure the weight of pycnometer together with inserted object m_0+m_s. We add water and determine the weight m'_{H2O} (measured weight minus m_0+m_s). The volume of added water V'_{H2O} can be obtained as

$$V'_{H2O} = \frac{m'_{H2O}}{\rho_{H2O}}$$

The volume of measured solid object VS is the difference between the volume of water that fills the empty pycnometer V and volume V'_{H2O}

$$V_S = V - V'_{H2O} = \frac{m_{H2O} - m'_{H2O}}{\rho_{H2O}}$$

Density of measured object ρ_s can be then calculated as

$$\rho_S = \frac{m_S}{V_S}$$

The following table shows us the values of the actual density and void content present in nano clay reinforced epoxy composites:

Table 4.1 Actual Density and Void Content in nanoclay reinforced epoxy composite

% Filler	Density of Nanoclay (gm/cm^3)	Density of Neat Epoxy (gm/cm^3)	Theoretical Density (gm/cm^3)	Actual Density (gm/cm^3)	Void Content (in %)
2	1.82	1.15	1.11	1.15	3.8
4	1.82	1.15	1.12	1.17	4.5
6	1.82	1.15	1.130	1.18	6.2

The following table shows us the values of the actual density and void content present in nano clay reinforced epoxy composites :

Table 4.2 Actual Density and Void Content in nanocarbon reinforced epoxy composite

% Filler	Density of Nanocarbon (gm/cm^3)	Density of Neat Epoxy (gm/cm^3)	Theoretical Density (gm/cm^3)	Actual Density (gm/cm^3)	Void Content (in %)
2	1.5	1.15	1.11	1.14	3.54
4	1.5	1.15	1.11	1.17	5.86

The above two tables show that with increase in the percentage of fillers the void content increases because with increase in the percentage of filler nanovoids increase into the nanocomposite plates.

4.2 3 point bending/Flexural Test :

Flexural tests were conducted on universal testing machine(UTM) used for in accordance with ASTM D2344-84. Specimens of 140 mm length and 15 mm wide were cut and were loaded in three points bending with a recommended span to depth ratio of 16:1 as shown in Fig.4.1. The test was conducted using a load cell of 10 kN at 2 mm/min rate of loading. The flexural stress in a three point bending test is found out by using equation.

$$\sigma_{\max} = \frac{(3P_{\max}L)}{(bh^2)} \qquad (5)$$

Where P_{max} is the maximum load at failure (N), L is the span (mm), b and h is the width and thickness of the specimen (mm), respectively.

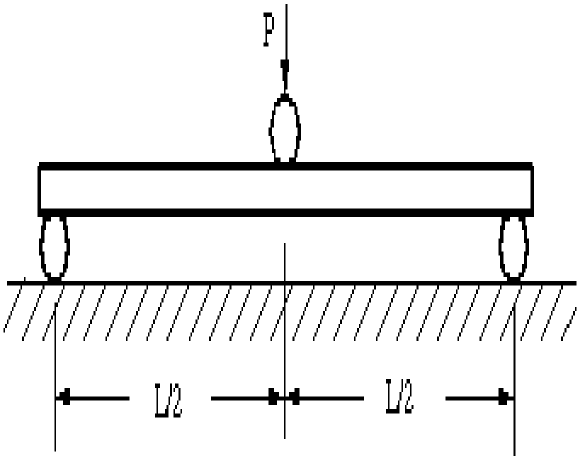


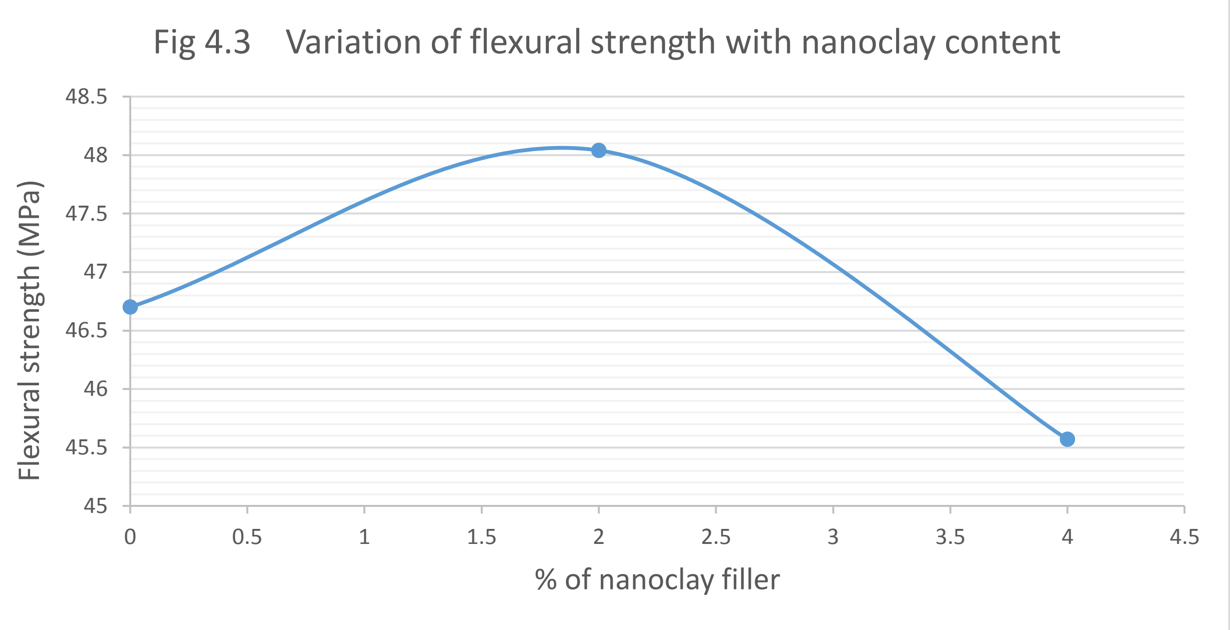
Fig 4.1 3 point bending test principle

Fig 4.2 Three point bending test sample/flexural test sample

The following table shows us the values of the flexural strength of the nano clay reinforced epoxy composites :

Table 4.3 Flexural strength of nanoclay reinforced epoxy composites

S.No.	Type of Sample	Flexural Strength (Mpa)
1.	Neat Epoxy	57.50
2.	2% Nanoclay + Epoxy	65.19
3.	4% Nanoclay + Epoxy	64.60
4.	6% Nanoclay + Epoxy	56.21



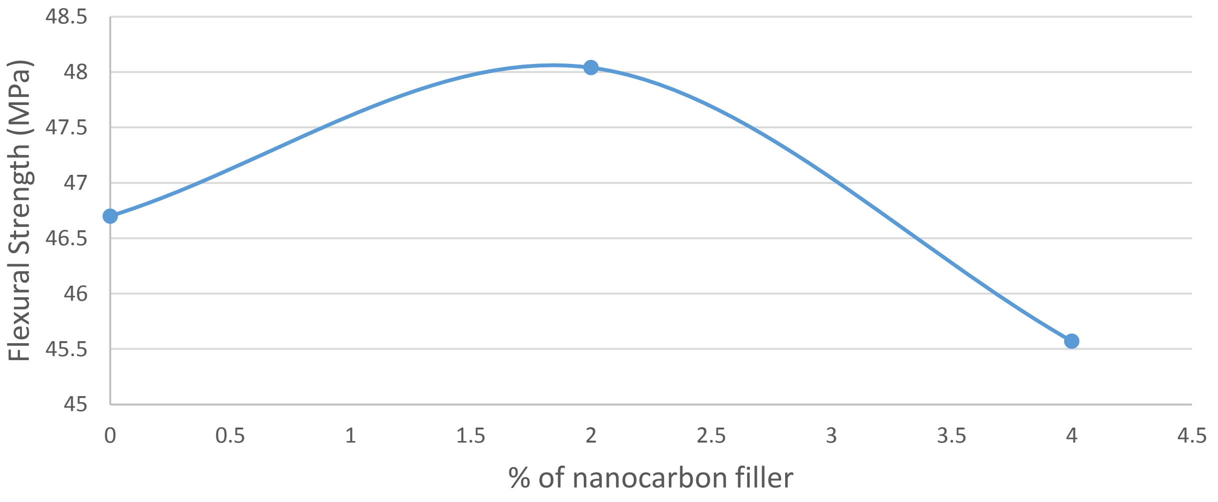
The above table and the curve show that 2% nanoclay and 4% nanoclay reinforced matrices have better flexural strengths as compared to neat epoxy but 4% nanoclay has inferior flexural strength when compared to 2% nanoclay reinforced composite. 6% nanoclay reinforced composite has lowest flexural strength and it is lower than that of the neat epoxy as well this is due to the increase in the agglomerates, inhomogeneities and nanovoids with increasing amount of the fillers.

The following table shows us the values of the flexural strength of the nano carbon reinforced epoxy composites :

Table 4.4 Flexural strength of nanocarbon reinforced epoxy composites

S.No.	Type of Sample	Flexural Strength (Mpa)
1.	Neat Epoxy	57.50
2.	2% Nanocarbon + Epoxy	59.93
3.	4% Nanocarbon + Epoxy	58.29

Fig 4.4 Variation of flexural strength with nanocarbon content



The above table and the curve clearly show that 2% and 4% nanocarbon reinforced composites have better flexural strengths as compared to that of the neat epoxy but 4% nanocarbon reinforced matrix has inferior flexural strength than that of 2% nanocarbon reinforced epoxy composite this is due to the incorporation if nanovoids into the matrix on increasing the filler content.

The following graphs depict the reinforcement content on the flexural strength of the epoxy composite:

Fig 4.5 2% Nanoclay reinforced epoxy composite curve

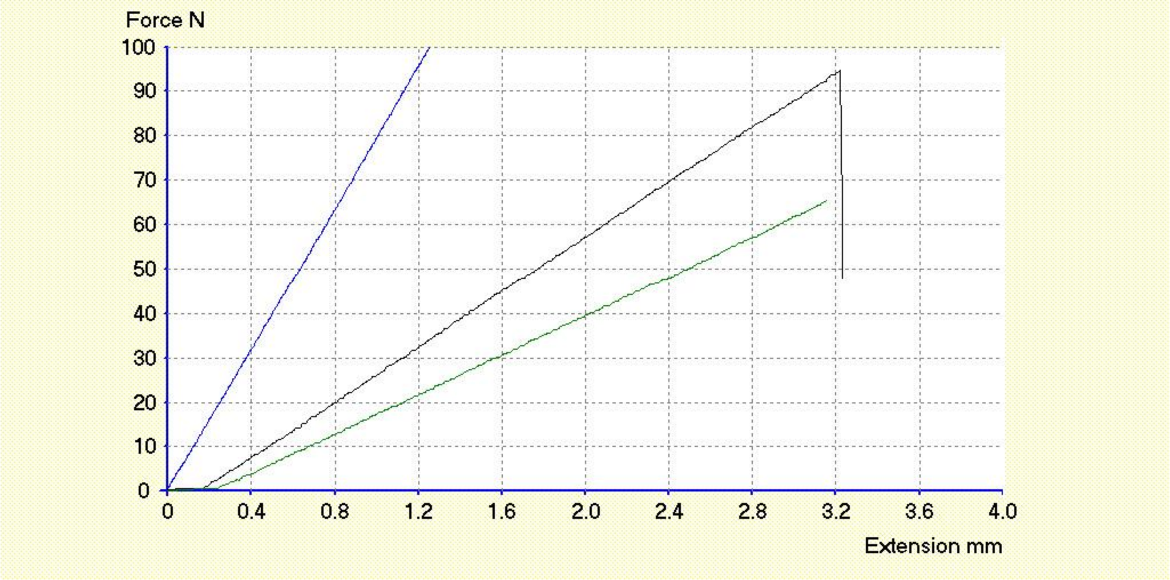


Fig 4.5 4% Nanoclay reinforced epoxy composite curve

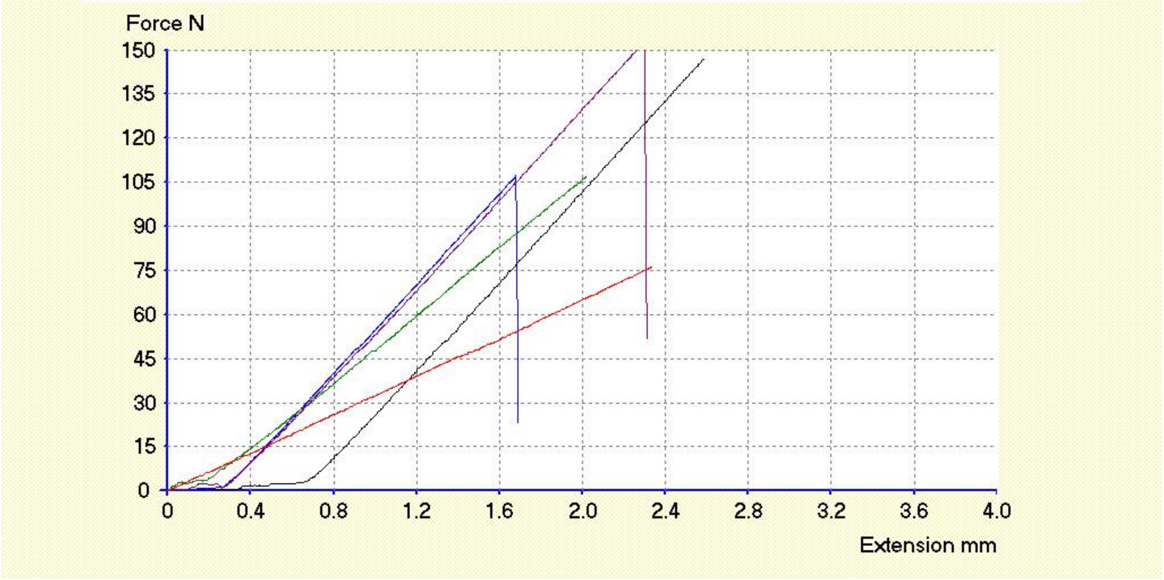


Fig 4.7 6% Nanoclay reinforced epoxy composite curve

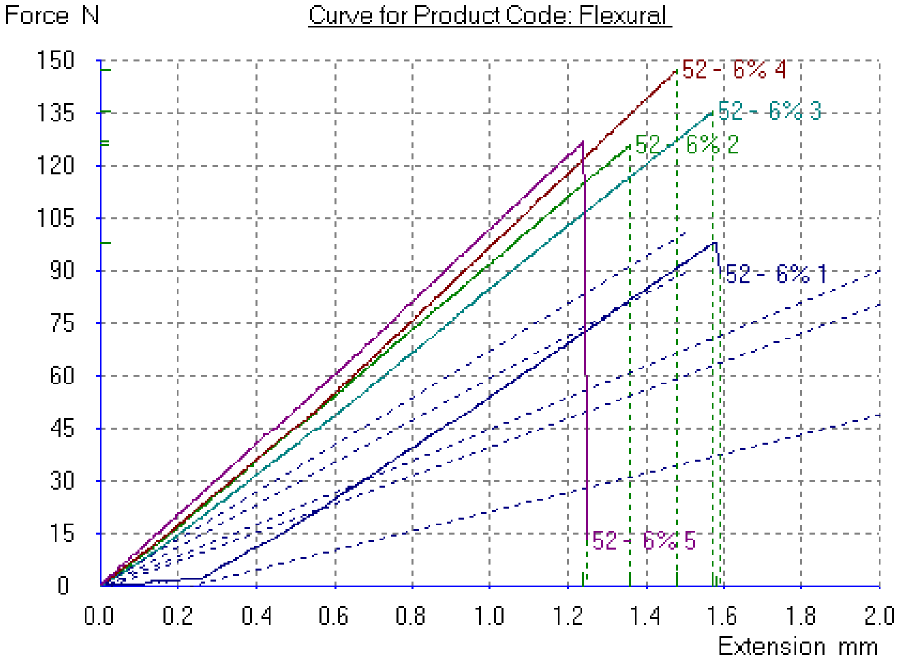


Fig 4.8 2% Nanocarbon reinforced epoxy composite curve

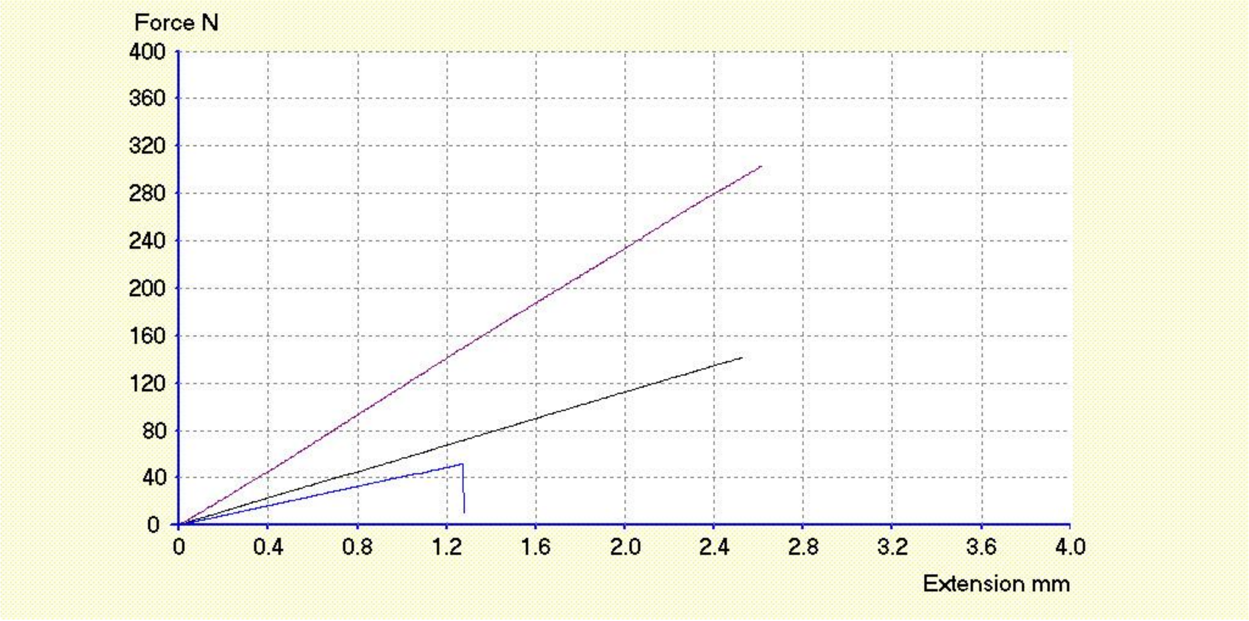
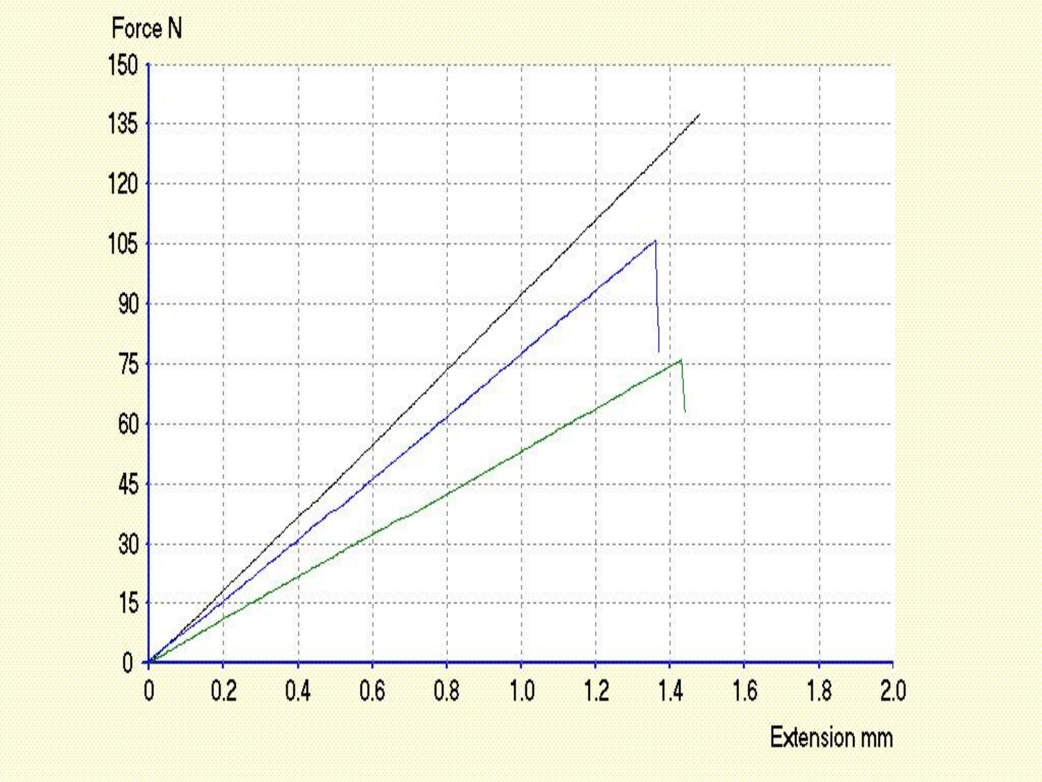


Fig 4.9 4% Nanocarbon reinforced epoxy composite curve



4.3 Tensile Test :

The tension test is generally performed on flat specimens. The most commonly used specimen geometries are the dog-bone specimen (Fig. 4.8) and straight-sided specimen with end tabs. The standard test method as per ASTM D 3039-76 has been used; length of the test specimen used is 140 mm. The tensile test is performed in universal testing machine. A rate of loading of 10 mm/min was used for testing. Tests were conducted on nanoclay reinforced and nanocarbon reinforced epoxy composite samples. For each stacking sequence, 4 identical specimens were tested and average result is obtained.

Fig 4.10 Dog bone shaped specimen for tensile test

The tensile strength is calculated using the following formula :

Tensile strength = Maximum Load / Cross sectional area

where,

Cross sectional area = Thickness*Gauge section length

The following table shows us the values of the tensile strength of the nano clay and nanocarbon reinforced epoxy composites :

Table 4.5 Tensile strength of nanoclay and nanocarbon reinforced epoxy composites

S.No.	Type of Sample	Tensile Strenght (MPa)
1.	Neat Epoxy	46.7
2.	2% Nanoclay + Epoxy	49.01
3.	4% Nanoclay + Epoxy	45.81
4.	6% Nanoclay + Epoxy	41.63
5.	2% Nanocarbon + Epoxy	48.04
6.	4% Nanocarbon + Epoxy	45.57

Fig 4.11 Variation of tensile strength with nanoclay content

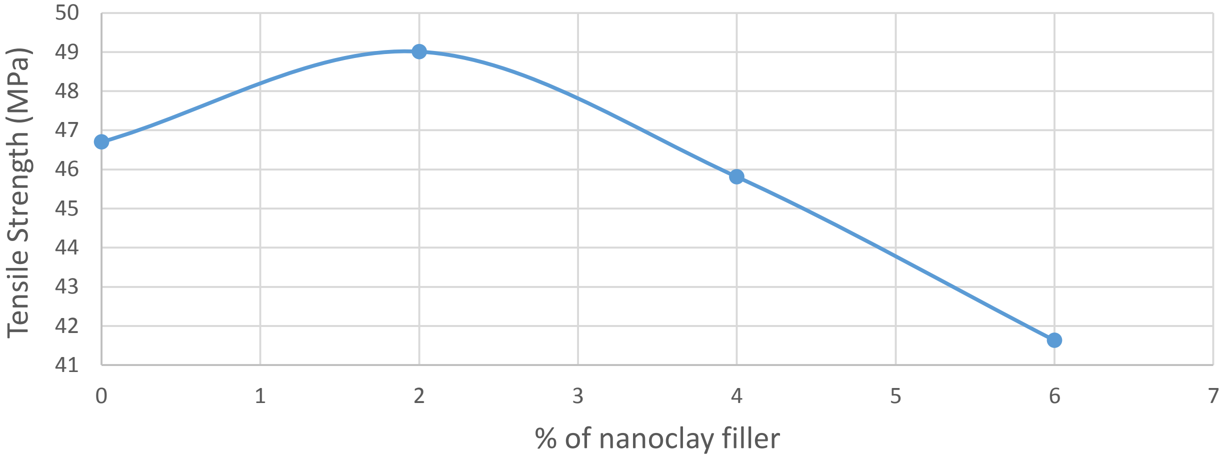
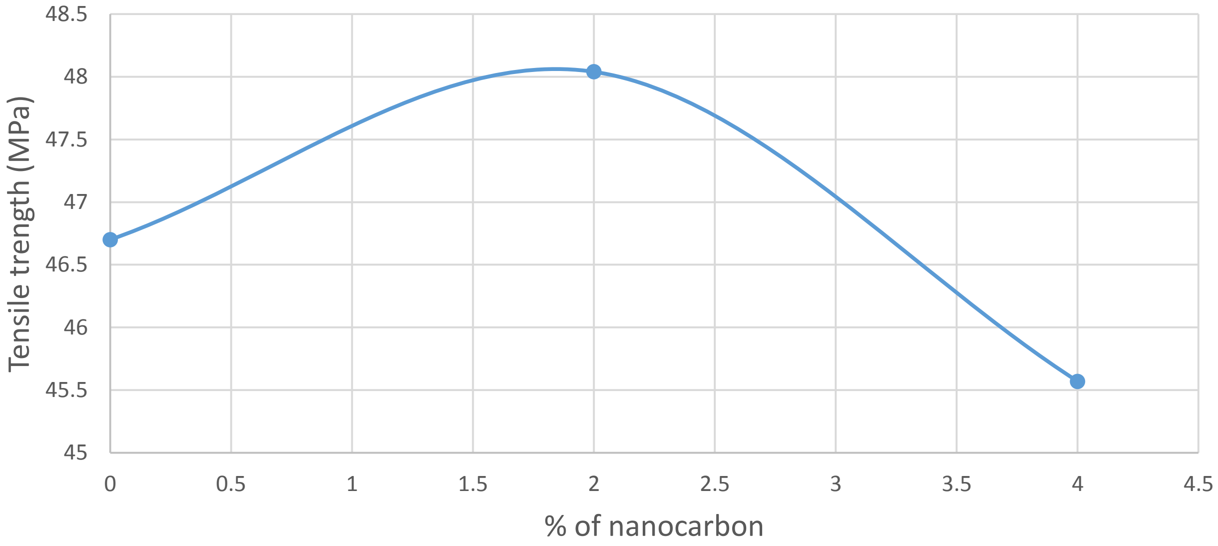


Fig 4.12 Variation of tensile strength with nanocarbon content



The above table and the curves show that with increase in percentage of fillers form 0 to 2% the tensile strength increases and it again decreases below that of the neat epoxy on further increasing the percentage of both nanoclay and nanocarbon fillers. This happens due to the formation of nanovoids into the reinforced epoxy and the agglomeration of the filler also takes place into the reinforced epoxy which is another cause of the deterioration of the tensile strength of the reinforced epoxy matrices.

4.4 Vicker’s Hardness Test :

The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 100 kgf. The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated. The area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation.

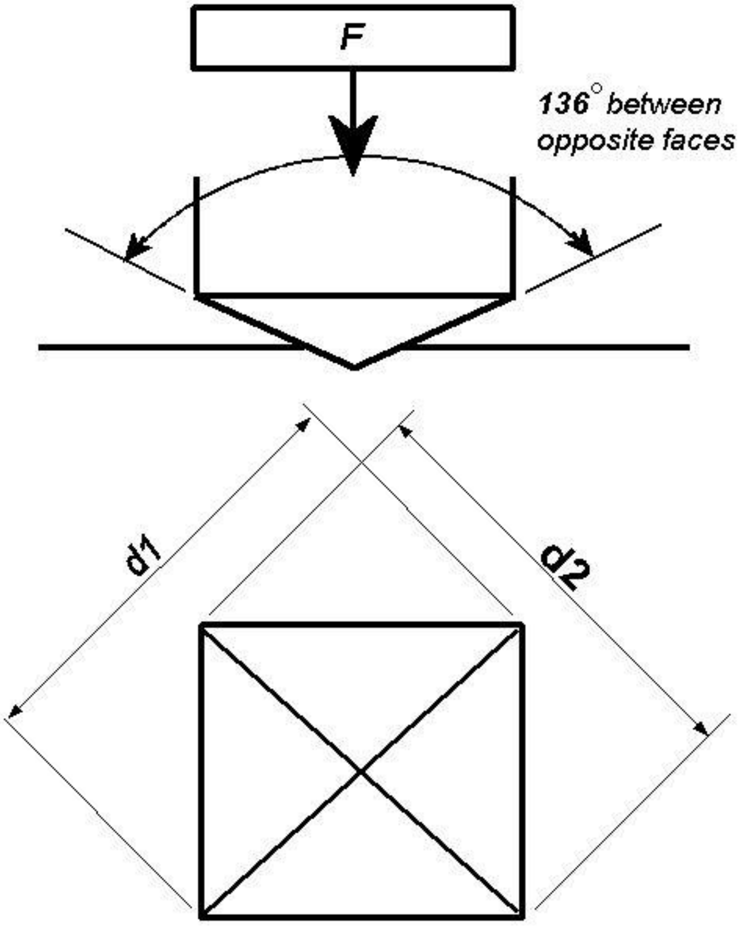


Fig. 4.13 Vicker’s Hardness principle

$$HV = \frac{2F\sin\frac{136^{o}}{2}}{d^{2}} \qquad HV = 1.854\,\frac{F}{d^{2}} \text{ approximately}$$

F=Load in kgf

d = Arithmetic mean of the two diagonals, *d1* and *d2* in mm

HV = Vickers hardness

When the mean diagonal of the indentation has been determined the Vickers hardness may be calculated from the formula, but is more convenient to use conversion tables. The Vickers hardness should be reported like 800 HV/10, which means a Vickers hardness of 800, was obtained using a 10 kgf force. Several different loading settings give practically identical hardness numbers on uniform material, which is much better than the arbitrary changing of scale with the other hardness testing methods. The advantages of the Vickers hardness test are that extremely accurate readings can be taken, and just one type of indenter is used for all types of metals and surface treatments. Although thoroughly adaptable and very precise for testing the softest and hardest of materials, under varying loads, the Vickers machine is a floor standing unit that is more expensive than the Brinell or Rockwell machines.

The following table shows us the values of the vicker's hardness of the nano clay and nanoclay reinforced epoxy composites :

Table 4.6 Vicker's Hardness of nanoclay and nanocarbon reinforced epoxy composites

S.No.	Type of Sample	Vicker's Hardness (HV)
1.	Neat Epoxy	20.2
2.	2% Nanoclay + Epoxy	22.5
3.	4% Nanoclay + Epoxy	23.2
4.	6% Nanoclay + Epoxy	24
5.	2% Nanocarbon + Epoxy	22
6.	4% Nanocarbon + Epoxy	22.6

Fig 4.14 Variation of vicker's hardness with nanoclay content

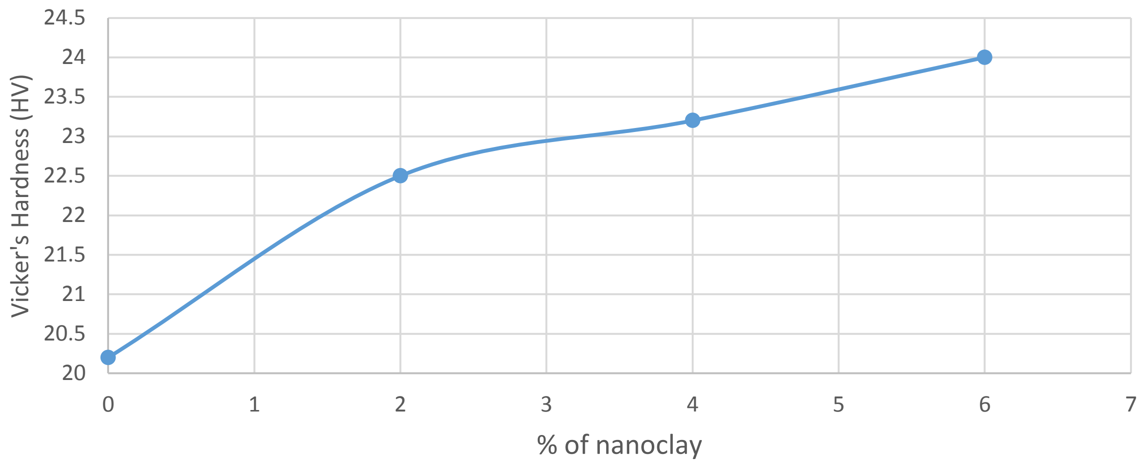
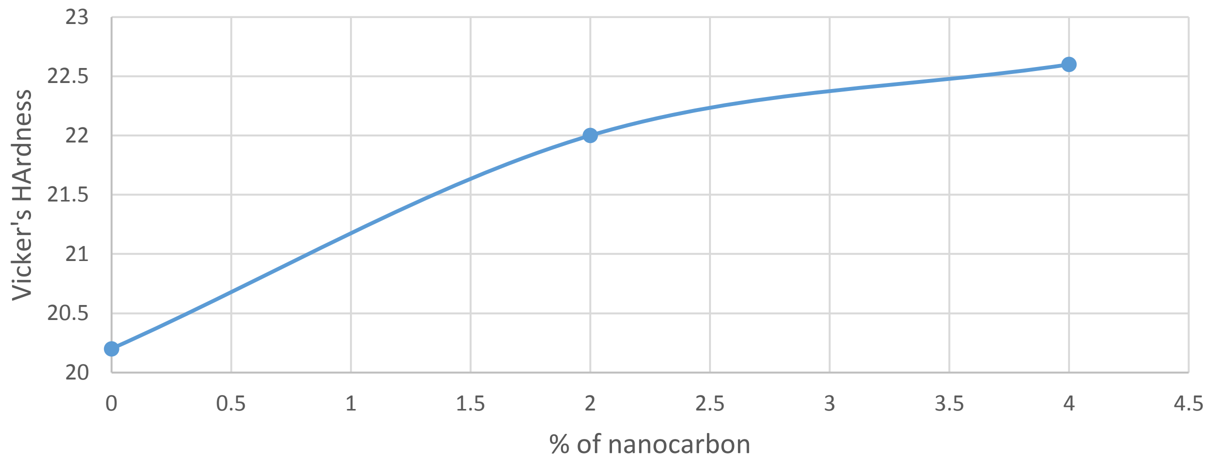


Fig 4.15 Variation of Vicker's Hardness with nanocarbon content



The above table and the curves indicate that with the increase in the percentage of the fillers (both nanoclay and nanocarbon) the vicker’s hardness value of the reinforced epoxy composite matrices keeps on increasing, the presence of nanoclay/nanocarbon clusters and the size of the agglomerates formed can be responsible for this kind of behavior.

CHAPTER-5

Conclusion

5. CONCLUSION:

Based on the tests carried out on the nano filler reinforced composites the following conclusions can be listed:

1) By incorporation of nanoclay and nanocarbon as fillers the mechanical properties such as flexural strength and tensile strength to some extent give encouraging results when compared with the neat epoxy but after a certain amount of addition of additives these properties get depleted/deteriorated.
2) The void content in reinforced epoxy matrices increases on increasing the percentage of filler content.
3) The hardness of the reinforced epoxy composites matrices also increases on increasing the percentage of filler contents.

REFERENCES:

1) http://en.wikipedia.org/wiki/Tribology
2) Jartiz, A.E., Design 1965, p.18.
3) Kelly, A. Sci. American 217, (B), (1967): p. 161.
4) Berghezan,A.Nucleus,8(5),1966,(Nucleus A Editeur,1,rhe,Chalgrin,Paris, 16(e).
5) Suchetclan Van, Philips Res. Repts.Volume 27, (1972): p. 28
6) Tewari US, Harsha AP, Ha¨ ger AM, et al. Solid particle erosion of unidirectional carbon fibre reinforced polyetheretherketone composites. Wear 2002; 252: 992–1000 Pool KV, Dharan CKH and Finnie I. Erosive wear of composite materials. Wear 1986; 107: 1–12.
7) Kulkarni SM and Kishore. Influence of matrix modification on the solid particle erosion of glass/epoxy composites.
8) Polym Polym Compos 2001; 9: 25–30.
9) Aglan HA and Chenock Jr. Erosion damage features of polyimide thermoset composites. SAMPEQ 1993; 24: 41–47.
10) Liu W, Qiu Q, Wang J, et al. Preparation and properties of one epoxy system bearing fluorene moieties. J Appl Polym Sci 2009; 113: 1289–1297.
11) Hattotuwa G, Premalal B, Ismail H, et al. Comparison of the mechanical properties of rice huskpowder filled polypropylene composites with talc filled polypropylene composites. Polym Test 2002; 21: 833–839.
12) Ismail H, Nizam JM and Abdul khalil HPS. The effect of a compatibilizer on the mechanical properties and mass swell of white rice husk ash filled natural rubber/linear low density polyethylene blends. Polym test 2001; 20: 125–133.
13) Luo S and Netravali AN. Mechanical and thermal properties of environmentally friendly green composites made from pineapple leaf fibers and poly (hydroxybutyrate-covalerate) resin. Polym Compos 1999; 20: 367–378.

14) Belmares H, Barrera A and Monjaras M. New Composite materials from natural hard fibers. Part 2.Fatigue studies and a novel fatigue degradation model. Ind Eng Chem Prod RD 1983; 22: 643–652.

15) (Definition of epoxy resin, noun, from the Cambridge Advanced Learner's Dictionary & Thesaurus, Cambridge University Press)

16) M. A. Marciano, R. Ordinola-Zapata, T. V. R. N. Cunha, M. A. H. Duarte, B. C. Cavenago, R. B. Garcia, C. M. Bramante, N. Bernardineli, I. G. Moraes (April 2011). "Analysis of four gutta-percha techniques used to fill mesial root canals of mandibular molars". *International Endodontic Journal* **44** (4): 321–329.

17) Gujjala Raghavendra, Shakuntala Ojha , SK Acharya and SK Pal. Jute fiber reinforced epoxy composites and comparison with the glass and neat epoxy composites.

18) S. Zainuddin , M.V. Hosur , Y. Zhou , Alfred T. Narteh , Ashok Kumar , S. Jeelani. Experimental and numerical investigations on flexural and thermal properties of nanoclay–epoxy nanocomposites.

19) J.A.M. Ferreira , L.P. Borrego , J.D.M. Costa , C. Capela. Fatigue behaviour of nanoclay reinforced epoxy resin composites

20) Jeena Jose Karippal, H.N. Narasimha Murthy, K.S. Rai, M. Sreejith, and M. Krishna. Study of mechanical properties ofepoxy/glass/nanoclay hybrid composites.

21) JAM Ferreira, PNB Reis, JDM Costa, and MOW Richardson. Fatigue behaviour of Kevlar composites withnanoclay-filled epoxy resin.

22) Andrea Dorigato, Stefano Morandi, and Alessandro Pegoretti. Effect of nanoclay addition on the fiber/matrix adhesion in epoxy/glass composites. Journal of Composite Materials, June 2012; vol. 46, 12: pp. 1439-1451.

23) Arun K. Subramaniyan and C.T. Sun. Interlaminar Fracture Behavior of NanoclayReinforced Glass Fiber Composites**.** *Journal of* Composite *Materials, October 2008; vol. 42, 20: pp. 2111-2122.*

24) Shafi Ullah Khan a, Arshad Munir b, Rizwan Hussain b, Jang-Kyo Kim. Fatigue damage behaviors of carbon fiber-reinforced epoxy composites containing nanoclay.

25) A. Haque, M. Shamsuzzoha, F. Hussain, and D. Dean. S2-Glass/Epoxy Polymer Nanocomposites: Manufacturing, Structures, Thermal and Mechanical Properties. *Journal of Composite Materials, October 2003; vol. 37, 20: pp. 1821-1837.*

26) Jia-Lin Tsai and Ming-Daw Wu. Organoclay Effect on Mechanical Responses of Glass/Epoxy Nanocomposites. *Journal of Composite Materials, March 2008; vol. 42, 6: pp. 553-568.*

,