EVALUATING THE OPTIMIZED PARAMETERS FOR THE DISPERSION OF NANOPARTICLES IN NANOCOMPOSITES

DISSERTATION-II

Submitted in partial fulfillment of the requirement for the award of degree

MASTER OF TECHNOLOGY
IN

(Mechanical Engineering)

SUBMITTED By

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I would also like to thank and acknowledge ATUL POLYMERS LTD. for supplying generously with Lapox epoxy, hardener and NANOSHELL LTD. for nanoclay for this experimentation. My special thanks are due to my family members and friends who constantly encouraged me to complete this study.

Rohit Sharma

CERTIFICATE

This is to certify that the Dissertation entitled "EVALUATING THE OPTIMIZED PARAMETERS FOR THE DISPERSION OF NANOPARTICLES IN NANOCOMPOSITES" is a bonafide record of independent research work done by Rohit Sharma (41200365) and submitted to Lovely Professional University, Jalandhar in partial fulfillment for the award of the Degree of MASTER OF TECHNOLOGY in Master of Mechanical Engineering.

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ABSTRACT

In this work, E glass fiber reinforced nanocomposites are manufactured with epoxy matrix modified with two different nanoclays: Cloisite 30B® and Cloisite 15A®. The nanoclays are dispersed in epoxy resin in different concentrations (1 wt.% and 2 wt.%). Two ply fibers (±450 stacking sequence) reinforced composites are manufactured using modified epoxy by vacuum assisted resin infusion moudling (VARIM). The baseline data for comparison is generated by carrying out test on neat epoxy glass fiber composite i.e. without nanoclay. Xray diffraction indicates that an intercalated nanoclay epoxy composite is obtained. Elastic modulus, flexural strength and micro-hardness are improved with incorporation of nanoclays.

Highest improvement in flexural strength, tensile modulus and micro-hardness obtained at 2 wt.% Cloisite 30B® nanoclay. The flexural strength and tensile modulus of E glass epoxy composite increased by 59% and 69.8% with 2 wt.% Cloisite 30B® nanoclay. The improvement in the properties may be attributed to the high aspect ratio, contact surface and reinforcing effects of nanoclays.

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NOMENCLATURE AND ABBREVIATIONS

1	GFRP	Glass fiber reinforced composites
2	VLSI	Very large scale integration
3	PNC	Polymer nanocomposites
4	OMMT	Monomorilloniteorganoclay
5	FRP	Fiber reinforced polymers
6	PU	Polyurethane
7	VARIM	Vacuum assisted resin infusion moulding
8	MMT	Manomorillonite
9	TEM	Transmission electron microscope
10	XRD	X-ray Diffraction
11	ASTM	American Society for testing and materials
12	GFRC15A	Glass fiber reinforced nanocomposite with Cloisite 15A
13	CFRP	Carbon fiber reinforced composites
14	GFRC30B	Glass fiber reinforced nanocomposite with Cloisite 30B®

1.1 COMPOSITE

Composites are materials composed of two or more different materials bonded together with one serving as the continuous matrix and other as a reinforcing material. The properties of the composites are superior to those of the individual materials that make up the composite. Different types of materials such as metals, ceramics, glasses and polymers may be combined in composite materials and in different forms.

Composites are a class of engineering materials possess superior properties of high strength and corrosion resistance over conventional materials. The other advantages of composites over common engineering materials.

Usually composites have these two phases:

1.2 MATRIX PHASE

Matrix are having a continues phase and posses ductile effects and having less hard phase. It has the high value of dispersion and can withstand load more as compare to secondary phase.

1.3 DISPERSED (REINFORCING) PHASE

The secondary phase is known as dispersed phase and it has discontinue form. This phase shows more strength than the matrix so thst why it is also known as reinforced phase.

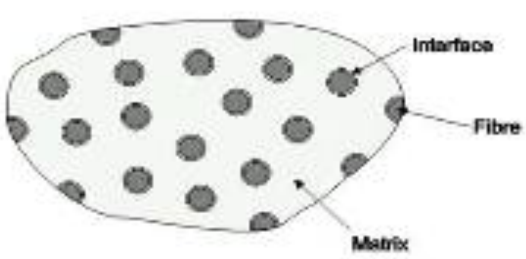

Fig.1.1 Dispersed phase

1.4 PROPERTIES OF COMPOSITE

- Stronger and light in weight
- They possess high resistance to corrosion, chemicals and other weathering agents
- They can be molded to any shape and size with required mechanical properties in different directions
- High creep resistance
- Capable of working at elevated temperature.
- High toughness
- Outstanding durability
- Composites have excellent RAM features (Radar absorbing materials)
- Low Density and light weight
- Strong & Ductile,
- Can be both insulators and conductors.
- High Temperature Resistant,
- Hard, but shock resistant,
- Wear Resistant.

2.1 APPLICATIONS OF COMPOSITE MATERIALS

Following are the main applications of composites material:

1. Extensively used in production of Aerospace Components.

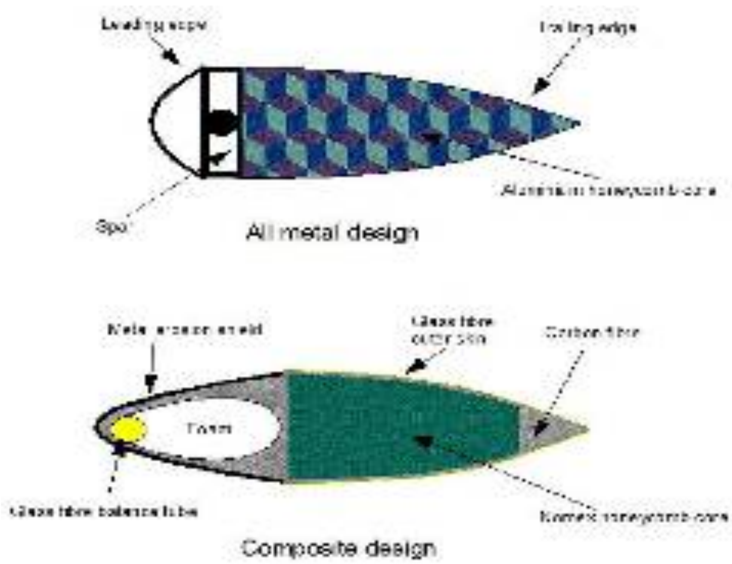

Fig.2.1 Rotor Blade Design

2. Used in constructions of bridge, domes, pipes and towers.
3. Also used in various sports goods like hockey sticks, tennis balls and surfer boards.
4. The use of fiber reinforced polymers (FRPs) in wind turbines because it exhibit excellent fatigue strength and require minimal maintenance.
5. Used in the production Body panels of racing car bodies, passenger cars and bicycle frames.
6. Composite are also used for manufacturing leaf springs for suspensions and drive shafts.
7. With the various orientation in the internal complex structure of the composites Tyres can be manufactured.

8. Composites mixed with reinforce synthetic carbon fibre can be used for the manufacturing of wires and polyester.

9. The Airbus 320 uses composites to make fin, fuselage and tail plane which allowed weight-saving of 800 kg over its equivalent in aluminum alloy as shown in fig. 2.1

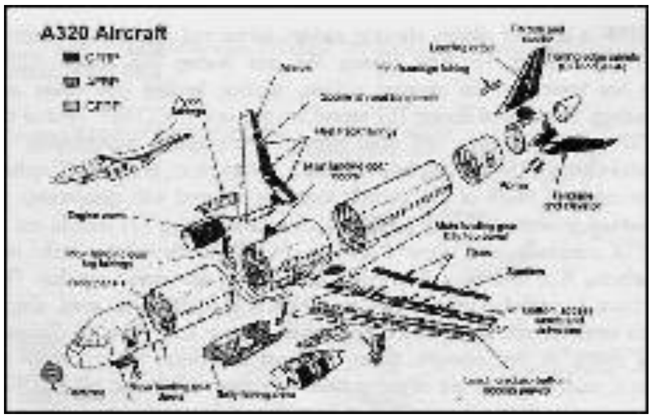

Fig.2.2 Aircraft

10. Critical applications of composites in the civil engineering area are:

- Bridge deck
- Stringer
- Beam
- Abutment panel
- Rebar
- Dowel bar
- Pole and post
- Signboard and signpost
- Guardrail system
- Sound barrier
- Drainage system (pipe, culvert)

3.1 FIBRE REINFORCED POLYMERS (FRP)

FRP also known as fibre reinforced plastic which is the combination of polymer as the base matrix and reinforced with fibers. The fibers which could be used for reinforced are carbon and glass fibre mixed with epoxy which will work as polymer or any polyester or any thermo plastic material. FRP have many engineering applications and very good response after the application of load it shows axial tension and regain its shape and size after the removal of load thus shows good elastic properties.

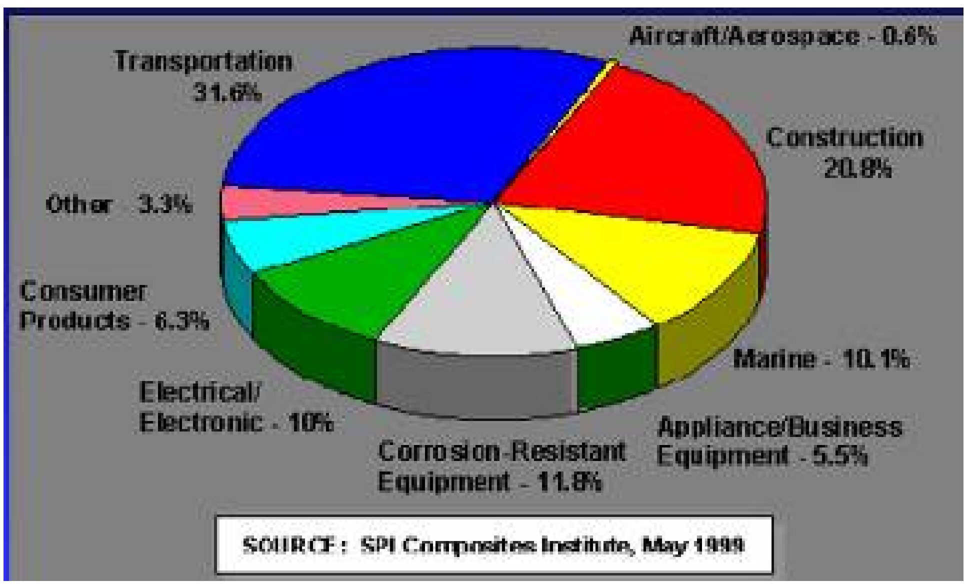

Fig 3.1 FRP usage

FRP are composites used in many engineering applications like airplane, aircrafts, boats, dams, bridges and even in civil constructions also.

Fiber Reinforced Polymer (FRP) reinforcement have the high usage in Civil structure also theses FRP now days are the substitute for the steel structures. These FRP reinforced materials are light in weight as compare with steel structures or concrete structures and these FRP materials purposed high tensile strength and easy to handle and easy to use as compare with steel and concrete structures. These material posses elastic behavior up to a particular. These FRP materials have some weak points also like poor shear resistance and the also posses poor resistance to fire at elevated temperature and have some sensitive rapture effects also.

Fibers types commonly used:

- Carbon fiber
- Glass fiber
- Aramid fiber

Ways of Fiber orientation in FRP

- Unidirectional
- Bidirectional
    a) Angle Ply
    b) Cross Ply

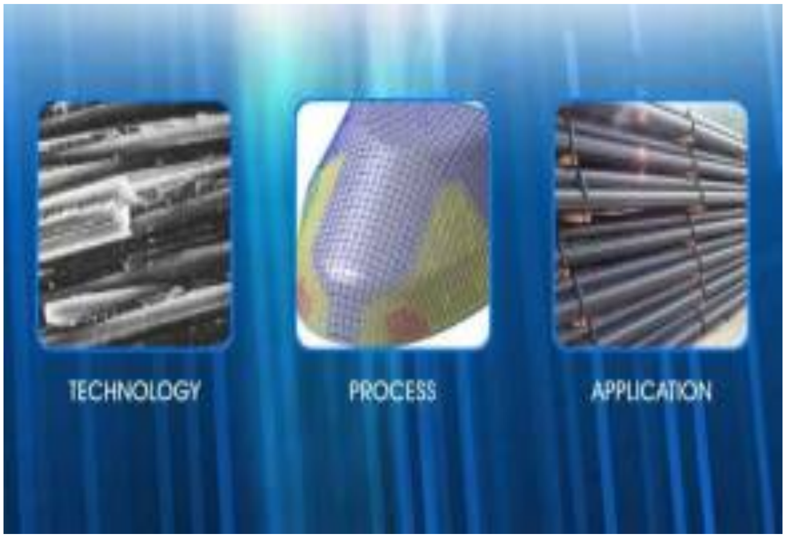

Fig 3.2 FRP

Types of polymer/matrix

- Epoxy
- Vinyl ester

3.2 APPLICATIONS

Fibre reinforced plastics are best suited for any design program that demands weight savings, precision engineering, finite tolerances, and the simplification of parts in both production and operation. A molded polymer artifact is cheaper, faster, and easier to manufacture than cast aluminum or steel artifact, and maintains similar and sometimes better tolerances and material strengths

3.3 CARBON FIBRE REINFORCED POLYMERS

Now days the overall market of the world is using fibre reinforced polymers to extra saving and high product value as well as long life of the particular product.

i) Highway structure

- Prodeck bridge system

Fig. 3.3 Meshed bridge system

- Auto skyway

Fig 3.4 Skyway

ii) Utility poles

Fig 3.5 Power transmission eletrical poles

iii) Pipes

Fig 3.6 FRP pipes

iv) Wind energy

Fig 3.7 Wind mills

v) Blast protections of structures

vi) Decking for navy and marine

Fig 3.8 Navy deck

vii) Army bridging

viii) Air force towers

ix) Carbon fibre polymer

Fig.3.9 Carbon Fibre Reinforced Polymer

4.1 DEFINATION

A nano composite is defined as a composite material in which at least one dimensions of at least one component is in the nanometer size scale (< 100 nm). Nano composite has high surface to volume ratio of the reinforcing phase and high aspect ratio. Nano composites are found in nature, for example in the structure of the abalone shell and bone. Polymer/clay nano composites are materials composed of a polymer matrix and nanometer size clay particles. They exhibit significant improvements in tensile modulus and strength, reduced permeability to gases and liquids compared to the pure polymer. These property improvements can be achieved while retaining low density

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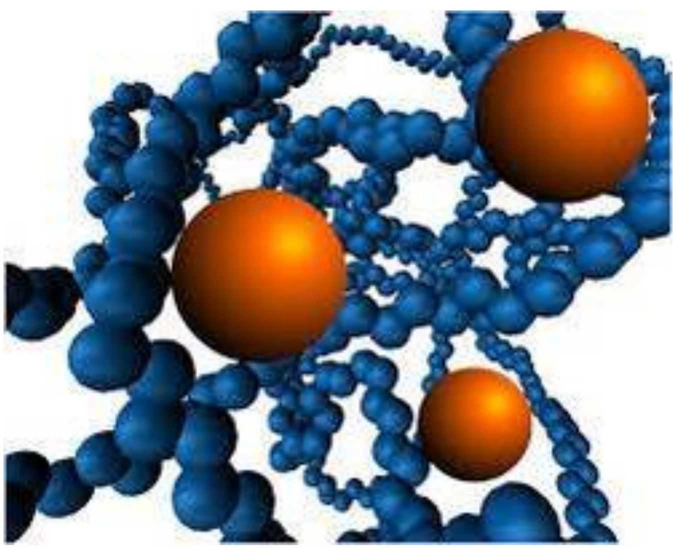

Fig. 4.1 Structure of nanocomposites

Nano composites are those materials which have multiphase and can posses one, two or three dimension phases, or the distance between the phases is less than 100 (nm), these nano composites includes gels and copolymers and all these shows different properties which depends upon internal structure and chemistry of the material.

The nano composites can increases the optical effect, mechanical effect, electrical and thermal effect of any material by adding these materials with a particular values. These nano composites can also be use to increase the magnetic effect of any particular material.

.a) Ceramic matrix nano composites

These are basically ceramic and produced by chemical compound from the family of nitrides, oxides, silicates and borides etc. These ceramic when mixed with nano particles form mixture with nano as dispersed phase and ceramic metal as base matrix which shows many nano properties and effects.

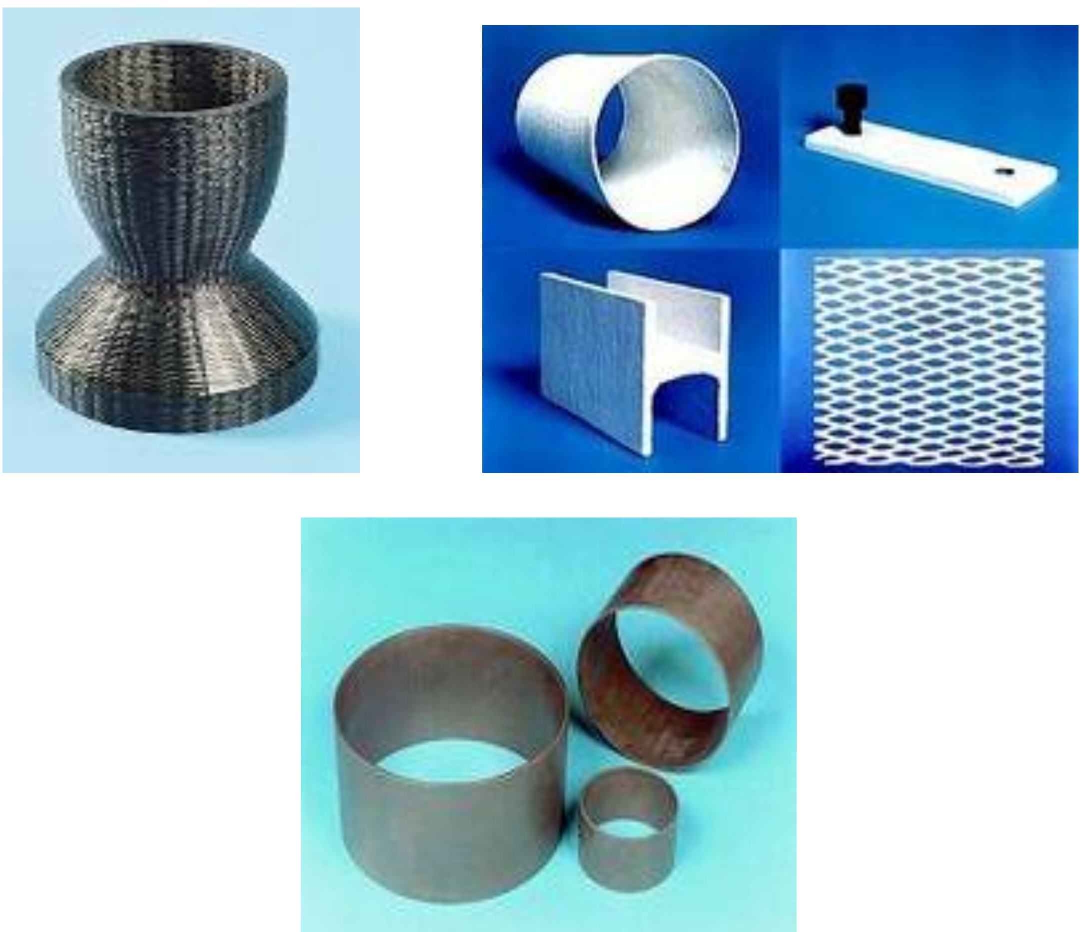

Fig 4.2 Components of ceramic-matrix nano composites

b) Metal-matrix nano composites

Metal matrix nano composites can also be defined as reinforced metal matrix composites. This type of composites can be classified as continuous and non-continuous reinforced materials. One of the more important nano composites is Carbon nano tube metal matrix composites, which is an emerging new material that is being developed to take advantage of the high tensile strength and electrical conductivity of carbon nano tube materials.

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Fig.4.3 Components of Metal-matrix nano composites

c) Polymer-matrix Nano Composites

In the simplest case, appropriately adding of nano particulates to a polymer matrix can enhance its performance, often dramatically, by simply capitalizing on the nature and properties of the nano scale filler (these materials are better described by the term nanofilled polymer composites. Nanoparticles such as graphene, carbon nano tubes, molybdenum disulfide and tungsten disulfide are being used as reinforcing agents to fabricate mechanically strong biodegradable polymeric nano composites for bone tissue engineering applications.

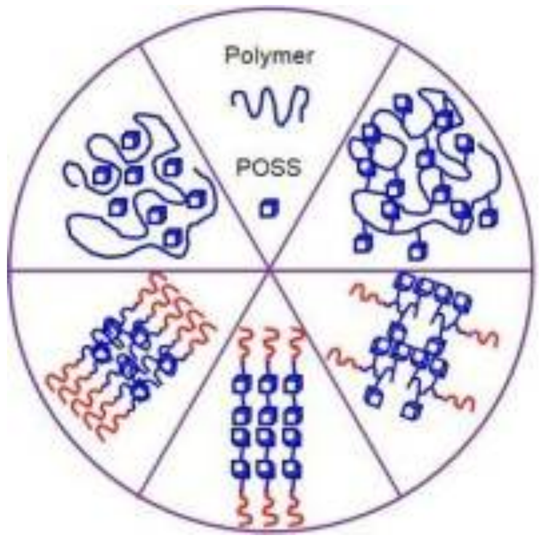

Fig 4.4 Structure Polymer-matrix nano composites

4.2 Properties

- Mechanical properties
- Gas barrier equipments
- Synergistic additive
- Good thermal effect
- Enhanced thermal conductivity
- Resistance to corrosion
- Reinforcement

4.3 Disadvantages

- Viscosity increases(limits process ability)
- Dispersion issues.
- Optical issues.

- Sedimentation.
- Black color when different carbon containing nano particles are used.

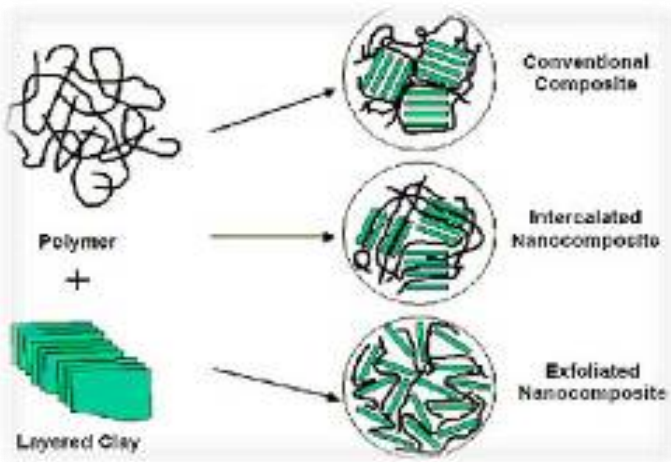

Fig 4.5 Microscopic view of nano composites

The first practical application of nano composites was in the use of nylon-montmorilloniteclay nano composite as a timing belt cover on a Toyota Camry automobile . This nano composite exhibited large increases in tensile strength, modulus, and heat distortion temperature without loss of impact resistance: it was shown that at a loading of only 4.2wt% clay, the modulus of nylon-6 was doubled; the strength increased more than 50%, and the heat distortion temperature increased by 80°C. It was further demonstrated that nanoclay greatly improved the dimensional stability, the barrier property and even flame retardant property. The composite had lower water sensitivity, lower permeability to gases, and lower coefficient of thermal expansion It mainly depends up on clay dispersion.

Commonly used nano fillers are:

- Nano tubes
- Nano clay
- Silica

4.4 Nanoclay

Nanoclays are nano particles of layered mineral silicates. Depending on chemical composition and nanoparticle morphology,nanoclays are organized into several classes such as montmorillonite, bentonite, kaolinite, hectorite, and halloysite. Organically modified nanoclays (organoclays) are an attractive class of hybrid organic- inorganic nano- materials with potential uses in polymer nano composites, as rheological modifiers, gas absorbents and drug delivery carriers.

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Fig 4.6 Nanoclay

4.5 Montmorillonite (Mmt) Nanoclay

Plate-like montmorillonite is the most common nanoclay used in materials applications. Montmorillonite consists of ~ 1 nm thick aluminosilicate layers surface- substituted with metal cations and stacked in ~ 10 µm- sized multilayer stacks. Depending on surface modification of the clay layers, montmorillonite can be dispersed in a polymer matrix to form polymer- clay nanocomposite.Within the nanocomposite individual nm- thick clay layers become fully separated to form plate - like nanoparticles with very high (nm × µm) aspect ratio.

4.6 Areas of applications

Following are the main area of applications of the nano composites:

- **Fuel Tanks**

Fig. 4.7 Vehicle Fuel tank

Fig. 4.8 Storage fuel tank

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- **Flammability Reduction**

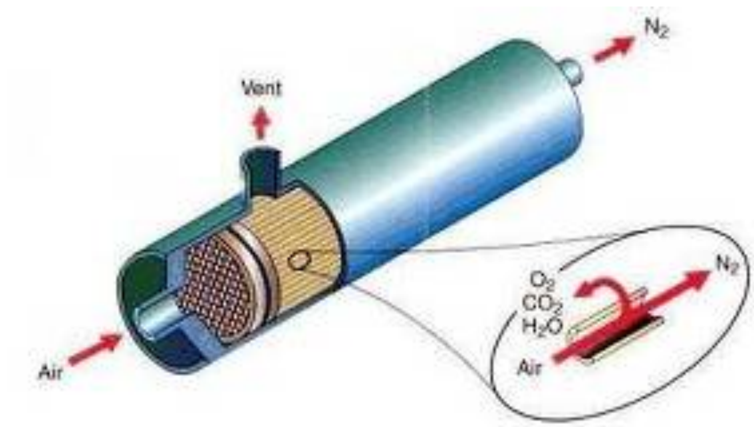


Fig. 4.9 Cooling media

Extensive literature review has been carried out for defining the research problem. Most of the work carried out is on the characterization of composites made by adding nanofillers to matrix system.

Yasmin et al (2006) investigated that with the mixing of nanocomposites with concentration wt% of clay particles were mixed. The mechanical and viscosity of the material recorded and according to the study it was found that the value of viscosity and the mechanical behavior of the material changed with the addition of nanocomposites. The thermal effect of the nanocomposite material also changes with the increment is temperature. With the help of thermo mechanical analyzer the value of coefficient thermal expansion was calculated

. **Manjunatha et al. (2009)** tests the tensile fatigue behavior of a silica nanoparticle-modified glass fiber reinforced epoxy composite. An anhydride-cured thermosetting epoxy polymer was modified by addition 10 wt. % of well-dispersed silica nanoparticles. The fatigue life of 10 wt. % silica nanoparticle-modified bulk epoxy is about three to four times higher than that of neat epoxy due to reduced crack propagation rate.

Urmimala Maitra et al. (2009) investigated when nanodiamond (ND) particles mixed or synthesized with polyvinayl alcohol (PVA) a nanocoposites polymer is formed which shows result of small angle X-ray scattering(SAXS) and transmission eletro microscopy(TEM) that a uniform distribution of nanodiamond was dispersed over the matrix base with no assemblage of the nanodiamond particles. Thus the results shows that with the small addition of the ND particles there is a increase in the hardness of PVA.

. **Zainuddin et al. (2010)** investigated with the help of vacuum assisted resin infusion moulding(VARIM) and the nanocomposite which is the mixture of I-28E nanoclay and E-Glass a glass fibre reinforced composite was formed and this particular material when reacted with dry and cold, wet and cold and at the end at elevated temperature and wet conditions thus the X-ray diffraction (XRD) results shows a new voids were dispersed over the matrix phase of the glass fibre reinforced polymer(GFRP).

F. Aymerich et al (2011) used shear mixing was performed at 3500 rpm for 1 hour to get good dispersion of nanoclays by breaking of nanoclays clusters. To avoid overheating a water bath equipment was used. The results of low-velocity impact response indicated a significant improvement in the energy absorption capability with a decrease of the peak impact force due to nanomodification.

Jumahata et al (2012) studied the effect of montmorillonite clay on the compressive properties of Epikote 828 epoxy. The nanomer I.28E was dried at 60°C and epoxy was heated to reduce viscosity after this mixture was heated in oil bath at 80° for 2 hours. They investigated that Nanocomposites offer higher compressive stiffness when compared to the neat polymer caused mainly by the high stiffness nanoclay. Although the presence of clusters/agglomerates of intercalated nanomer I.28 and nanovoids reduced the compressive strength of the epoxy system. Premature failure is initiated by the weak interfacial adhesion between nanofillers and the matrix and the presence of nanovoids.

Rattikarn (2012) used twin screw extruder for the mixing of polymer and silica at the screw speed 60 rpm. The extrudate were cut and dried at 50º c for 12 hours to prevent from moisture. Mechanical performances improved by adding small amount of silica.

B.Sharma et al. (2012) used hand lay-up method for preparing fiber reinforced nanocomposites. Epoxy was mixed by using Cloisite 30B nano clay and E- glass unidirectional fibers were used. XRD results indicate the intercalation of polymer between clay layers. The result shows the variation in tensile strength and enhanced value of micro hardness. The flexural strength may vary with the increment in the clay loading.

Rajmohan et al (2013) uses cooper oxide as nanofillers in polystyrene resin for making FRP using hand layup method. They concluded that the increase in wt % of nanoCuO improves the mechanical properties mainly due to the very large surface area of interaction between polymer matrix and nano filler. The linear regression model indicated the similar results as achieved by experimental work

Shivraj et al (2014) The sandwich structure composed of bidirectional E-glass fiber, Closite 30B nanoclay, epoxy resin and high density thermocol. Hand layup method was used for fabrication of sheets also the nanoclay percentage was varied subjected to various test. The use of nano composite increases the bending strength up to 41% as compared to virgin epoxy. The natural degradation of bending specimen with neat epoxy showed the maximum degradation up to 10% and it was 5% in case of specimens with nano composite sheets. The water resistance property of epoxy was improved by the addition of both glass fibre and nanoclay. The tensile strength is raised by 33% by using 3% of clay in the epoxy. The SEM and XRD were performed for characterization of the nano composites.

6.1 PROBLEM FORMULATION

These days the demand of nano composites increases in every field especially in engineering because of the light weight structure and improved mechanical properties as compare to natural resources. These are also used in aviation because it shows great potential of absorbing energy and enhanced flexural strength without any breakage up to particular point.

The required result is to vary the distance between the laminates and to enhance the shear stress property of the material with variation in the composition and thickness of the layered material of the face sheet of FRP structures; it is possible to obtain various properties and desired performance. From the literature survey related to glass fibre sandwich structures the following gaps were identified.

- No experimental data related to mechanical properties, using nano composites as face sheets available.
- Experimentation data related to mechanical behavior FRP structure by using high density core and using nanocomposites face sheets not available yet.
- Environmental effects on nanocomposites face sheets for FRP structure for along time period have not been studied so far.

6.2 OBJECTIVES OF RESEARCH

From the various gaps the objectives of research are to study the impact that nanocomposites will have on polymer structures.

- The work is to study various properties of polymer structure by modifying epoxy with Nano clay in Fibre Reinforced Polymer composites. As nano composites has enhanced several properties of the face sheets.
- The optimal level of clay loading and thickness of core for FRP structures as found from the literature will be used to find the effect of both.

- The change in mechanical properties of the specimens under natural degradation at ambient temperature. To know what will be effect of environment on the structure's, wind mill blades and airplanes.
- The weight gain by samples will also be studied when exposed to water at ambient temperature.
- The characterization of face sheets will be done with the help of XRD and SEM Analysis.

After defining the research problem various materials were required so number of vendors were contacted. As most of equipment are available in our university but various testing machines are not available like SEM, XRD so have to contact other universities.

6.3 Preliminary Research

Material/Equipments/ Test	**Use**	**Availability/Company name**
Bidirectional E-glass fiber	Reinforcing phase	Madhu fabrics
Lapox L-12 and Hardner K-6	Matrix	Atul ploymers
Nanoclay	Fillers	Nanoshel
Container	Storing epoxy	Purchased
Weighing machine	Measuring clay and Epoxy	In chemistry lab
Gloves	Protection of hands	Purchased
Oil bath	heating base epoxy	In chemistry lab
Mechanical stirrer	proper dispersion of clay	In chemistry lab
Ultra sonicator	degasification	In chemistry lab
Steel scrapper	applying epoxy	Purchased
Universal Testing machine	For tensile test	In mechanical lab
X-Ray Diffraction Test	Morphology characterization	G.N.D.U. Amritsar
SEM (Scanning Electron Microscope)	Micro-structure of material	G.N.D.U. Amritsar

7.1 WORKPLAN

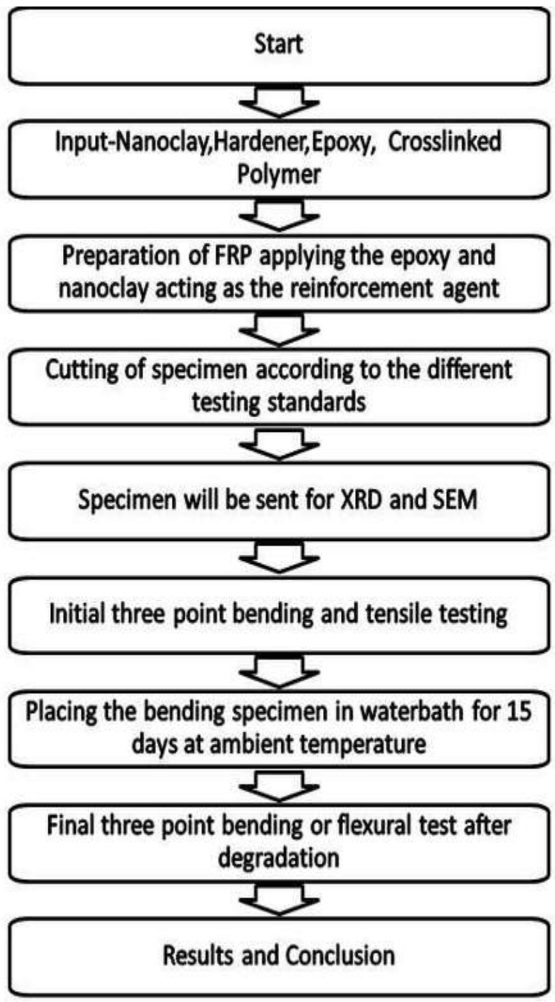


Fig 7.1 Flowchart of Work Plan

The fabrication of FRP composites had been performed using hand lay-up method, as it is economical than other in-situ techniques. Samples with various clay percentages were fabricated including one reference specimen without nanoparticles. Tensile and bending testing had been performed on each specimen to find out the load at failure, strain at failure and ultimate strength before and after natural degradation. Also SEM and XRD have been conducted for analyzing nano particle dispersion and material characterization.

7.2 FABRICATION OF SPECIMEN

a) Materials

Bidirectional E-glass fibre and Lapox a two part epoxy resin purchased from **Atul Ploymers (India) Private Limited**. Organically modified nanoclay Closite 30B purchased from **Intelligent materials.**

b) Apparatus Required For Fabrication

- Electronic weighing machine
- Magnetic stirrer with hot plate
- Homogenizer/ Mechanical stirrer
- Ultra Sonicator
- Glass beaker
- Steel Scrapper

c) Specimen Specifications

Commercially available glass fibre mat had been used for making specimen. The specimen had been cut and prepared as per the ASTM standard D3037/3039 for tensile.

Specifications for tensile test specimen

Length of specimen: 30 mm

Breadth of specimen: 25 mm

Thickness of specimen: 2 mm.

d) Methodology used for specimen fabrication

The methodology depends upon the following few steps as mention below:

i) Weighing of Nanoclay and Base epoxy

Firstly the base epoxy L-12, hardner K-6 and nano clay is measured using digital weighing machine in a glass beaker as per requirement. As nano clay is used in very small quantity as of 3-8 Grams we used paper as it adheres to beaker.

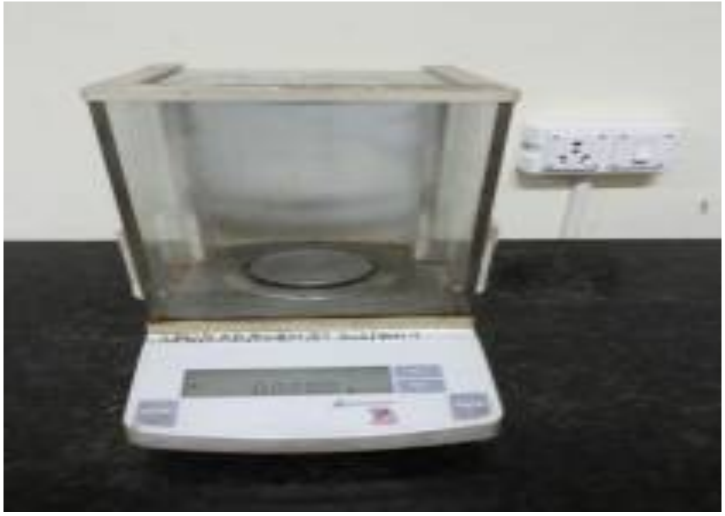


Fig 7.3 Digital weighing machine

ii) Mixing of Nanoclay into Epoxy (base)

First the base epoxy and required amount of nanoclay is measured with help of digital weighing machine. Epoxy base is a transparent thick fluid. It is quite difficult to mixnano silicates into it manually. So we used a homogenizer having RPM 2000 and a magnetic hot plate for proper mixing of nanoclay. Hot plate was used to heat up the epoxy to desired temperature (60o), so the viscosity of epoxy base is reduced. Proper mechanical stirring of epoxy at this stage resulted better dispersion of clay. The process of heating as well as stirring was performed simultaneously for 2hours to ensure the better dispersion to avoid agglomerates formation in the base epoxy. Different weight percentages of clay 1, 3 and 5 % by weight of epoxy, were added and stirred at a temperature of 600C for 2 hours.

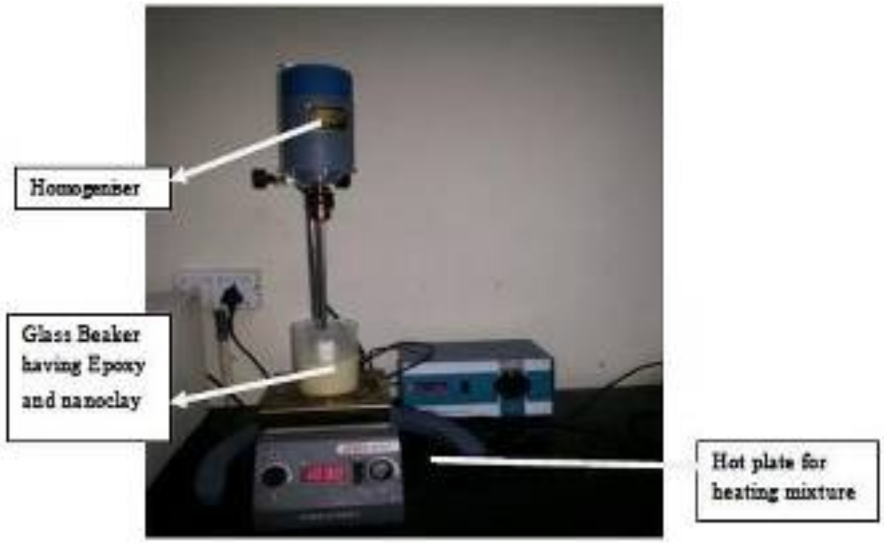


Fig 7.4 Set up for mixing clay in epoxy

iii) Ultrasonication

Ultra sonicator is an electrical apparatus which uses sound energy to resettle the nano particles. In the laboratory a ultra sonic bath tub is used for sonication and known as sonicator. Basically sonication is use for dissolution of the inter molecular interactions.it can also be used for dispersing nano particles in liquids. After stirring mechanically the epoxy solution container was placed into the ultra sonication bath for up to 2 hours.

Fig 7.5 Digital Ultra Sonicator

iv) Mixing of Epoxy Base Solution with Hardener

After ultra sonication, the solution is mixed with the hardener in the ratio 10:1 by volume. After mixing, manual stirring up to 5 to 10 minutes was done such that the hardener mixes properly in modified epoxy. The pot life of mixture is 15-20 min at ambient temperature.

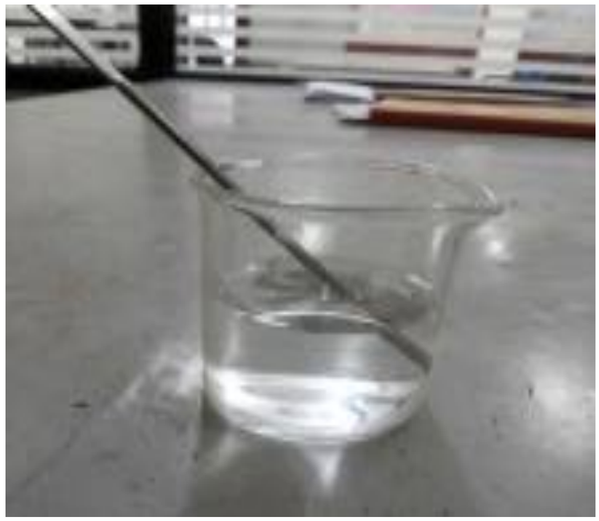


Fig 7.6 Glass beaker and spatula for mixing hardener

v) Coating with spatula

After mixing with hardner the gel formed mixture is now ready to be coated on the cross linked fibre so with the help so MS spatula a fine and thin layer of the gel mixture is coated over the cross linked fibre with approx 2mm thickness as shown.

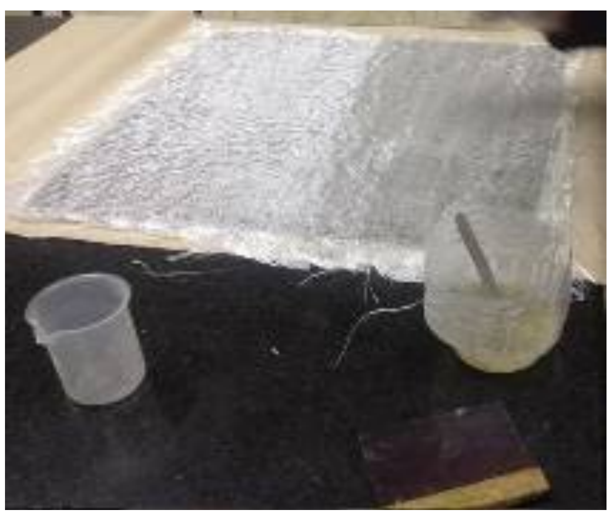


Fig 7.7 Coating of specimen with hardener

vi) Specimen after coating

After cooling the coated specimen for 24 hours in open air a fine layer of mixture gel is dispersed over the cross linked fibre as shown.

Fig 7.8 Coated Specimen

8.1 TENSILE TEST

To find out the tensile strength of the specimen a Universal tensile testing machine is used. The test specimen had been prepared according to ASTM-D-3039 standard. Load was kept on increasing gradually until the failure of the specimen.

Fig 8.1 Universal Tensile testing machine

The results obtained by conducting tensile tests on nano composites using Zwick/Roell

Specimens Name	Specimens No.	Tensile modulus (MPa)	Tensile strength (MPa)
0 wt.% clay	1	615	71.6
	2	542	63.2
	3	540	68.3

1 wt.% clay Cloisite 15A®	1	729	49.3
	2	746	49.3
	3	760	50.5
1 wt.% clay Cloisite 30B®	1	810	64.6
	2	801	65.0
	3	780	61.4
2 wt.% clay Cloisite 15A	1	856	65
	2	885	72.2
	3	850	60.6
2 wt.% clay Cloisite 30B®	1	962	64.3
	2	973	67.5
	3	967	64.4

Universal testing machine related graph with results are indicated below.

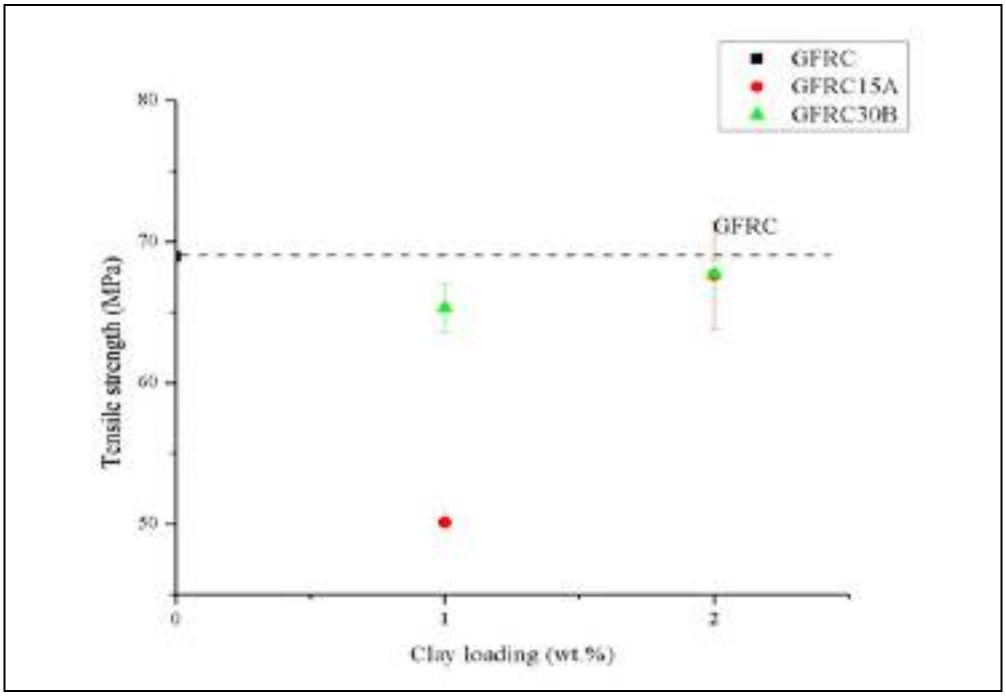


Fig 8.2 Tensile strength test results

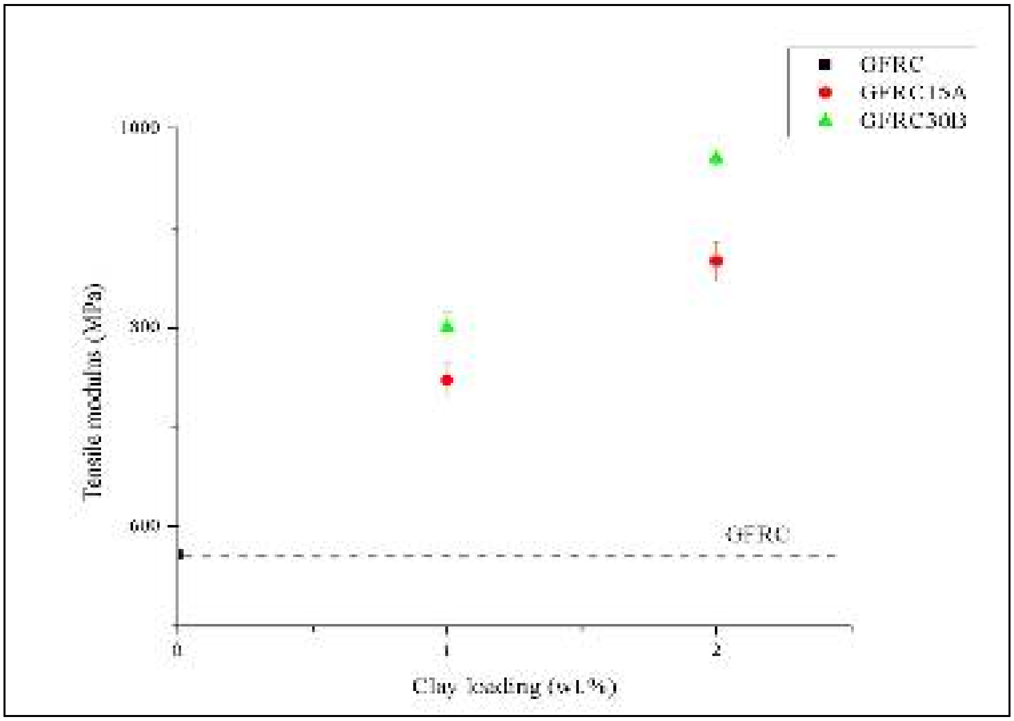


Fig 8.3 Tensile modulus test results

The failure of nanocomposite at strengths lower than pure epoxy might be thought to be process related. The aggravating of nanoclay in an epoxy matrix with homogenizer and ultra sonication produced viscous and foamy material and made degassing quite difficult. This in turn may leave some voids inside the nano composite. It might be thought that under tensile loading cracks can initiate from these tiny voids and cause specimens failure.

8.2 X-RAY DFFRACTION

Comparison of interlayer distance between clay platelets indicates that intercalated Nano composites.

	D001 spacing	
Clay loading	Cloisite 15A® [32.5 Å]	Cloisite 30B® [18.5 Å]
1 wt.%	41.8 Å	20.3 Å
2 wt.%	42.7 Å	21.12 Å

Compared to d001 spacing of 32.5 Å in Cloisite 15A®, the d spacing in the 1 wt.% and 2 wt.% increases to 41.8 Å and 42.7 Å. This suggests formation of intercalated morphology. Similar increase in d-spacing is observed for 1 wt.% and 2 wt.% Cloisite 30B®, suggesting an intercalated morphology.

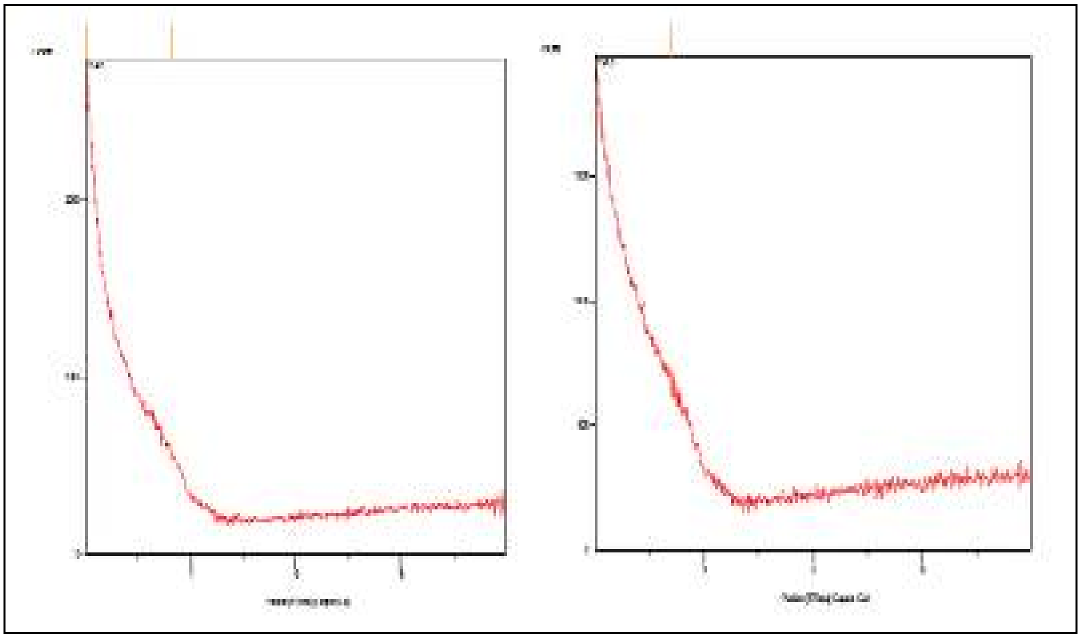


Fig.8.4

XRD results of specimens with 1 wt.% and 2 wt.% loading of nanoclayCloisite 15A®

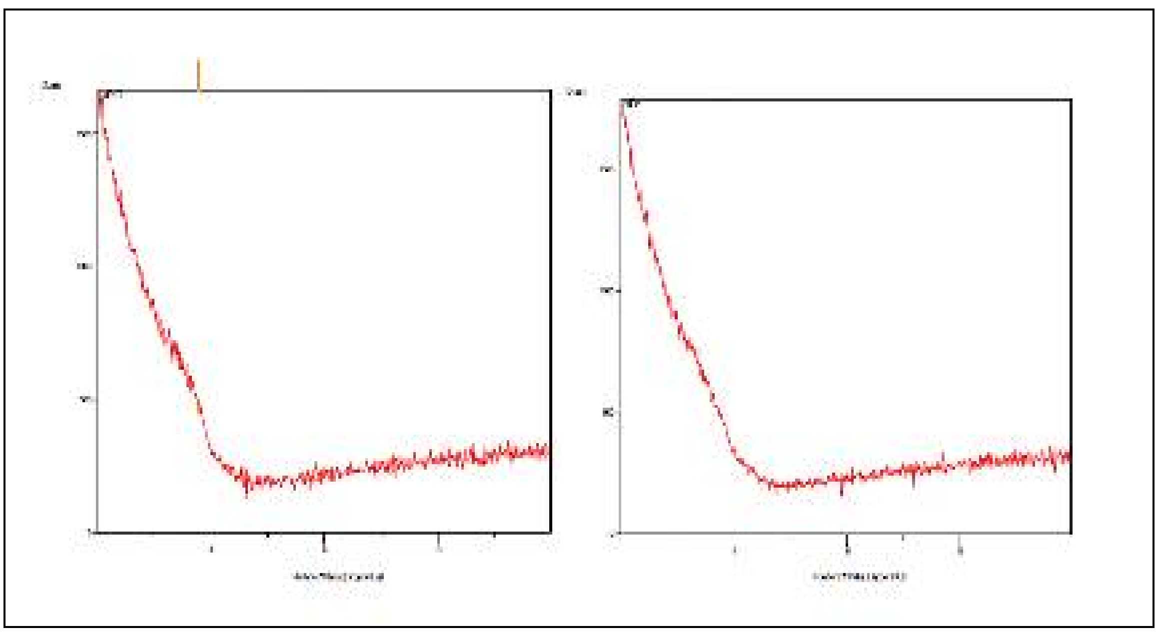


Fig 8.5

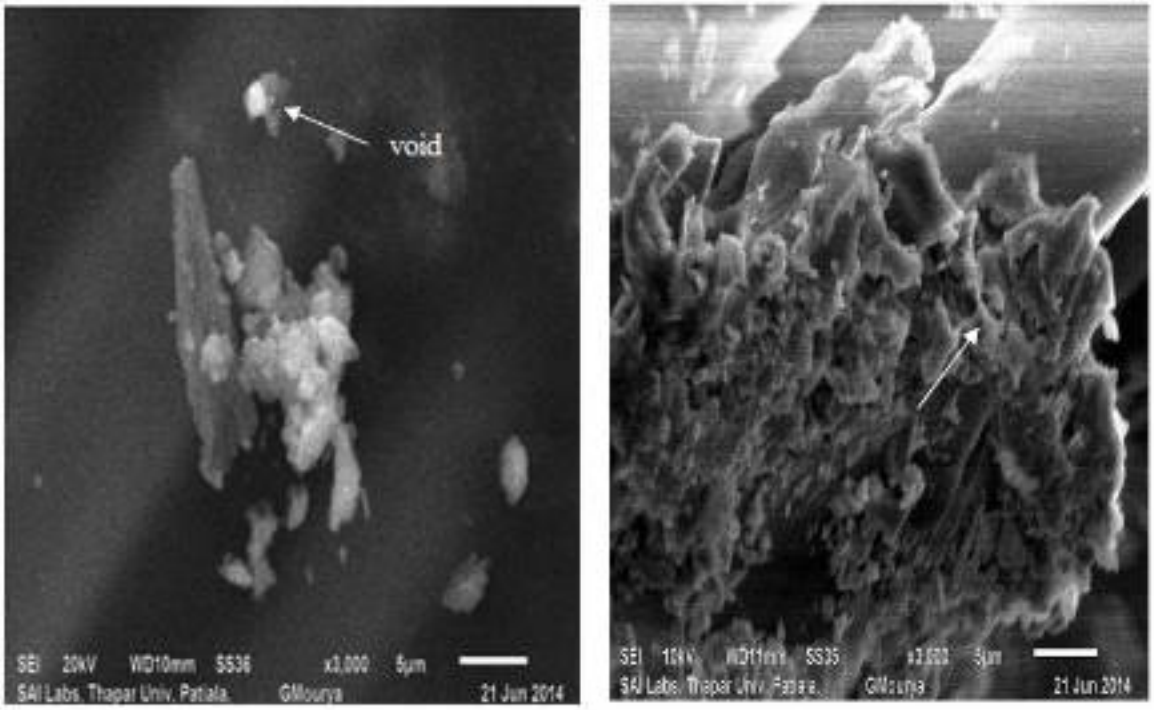
XRD results of specimens with 1 wt.% and 2 wt.% loading of nanoclayCloisite 30B®

8.3 SCANNING ELECTRON MICROSCOPES (SEM)

Samples were mounted onto sample holder and fixed with adhesive carbon tape. Fig. illustrates the top surface morphology of nanoclay composite flat sheet. Voids are observed as shown in figure 8.6.

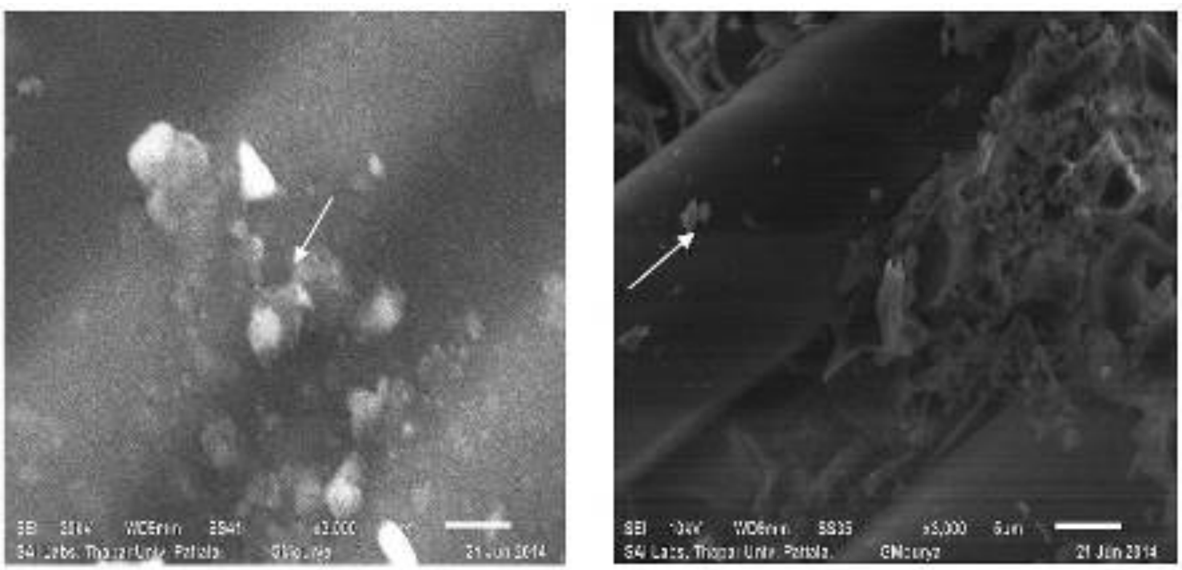
Fig 8.6 Scanning electron microscope

Non circular bright regions shows correspond clay agglomerates from are observed from SEM micrograph. It is observed clay particles are dispersed in the epoxy matrix and nanoclay is also distributed in the outside zone of glass fiber bundles in which epoxy resin flows.



(a) (b)

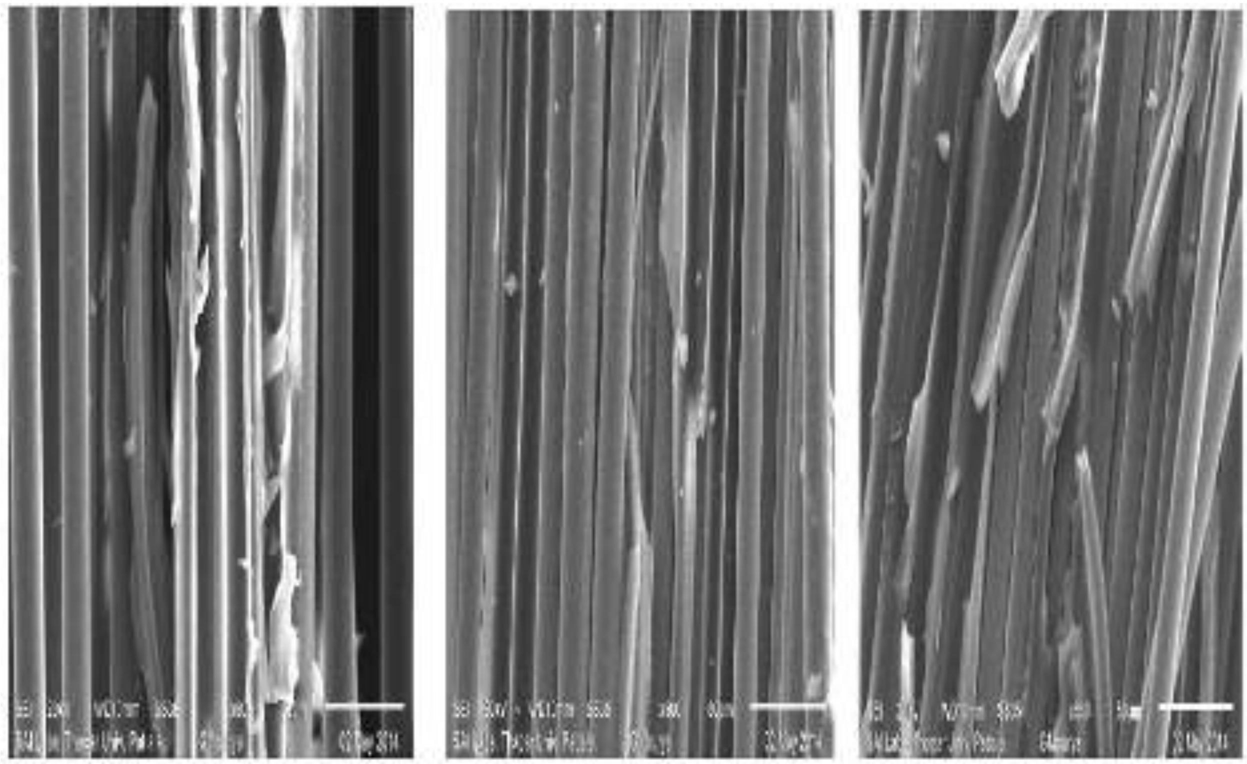
Fig 8.6 SEM image of specimens having nanoclay Cloisite 15A® (a) 1 wt.% and (b) 2 wt.%



(a) (b)

Fig 8.7 SEM image of specimens having nanoclay Cloisite 30B® (a) 1 wt.% and (b) 2 wt.%

In neat epoxy glass fiber composite smooth crack surface are framed because of weaker interfacial bonding in laminates as shown in fig. 8.6(a). In contrast with an addition of nanclay a rough fracture surface are formed as shown in fig. 8.6(b) and 8.7(a). The fracture modes indicate that an interface between nanoclay and epoxy is formed in these composites.



(a) (b) (c)

Fig. 8.8

SEM images of (a) 0 wt.% (b) 1 wt.% nanoclay Cloisite 30B® and (c) 1 wt.% Nanoclay Cloisite 15A®

CHAPTER 9 CONCLUSION AND FUTURE SCOPE

9.1 CONCLUSION

1. In this project the E glass fiber reinforced epoxy-nanoclay composites are manufactured using vacuum assisted resin infusion moulding. Addition of nanoclays resulted into improvement in mechanical properties of fiber reinforced composites (micro hardness, flexural strength, tensile modulus). 2 wt.% Cloisite 30B® nanoclay reinforced specimens showed the best combination of properties. The apparent lower or no enhancement in tensile strength of glass fiber reinforced nano composite over glass fiber reinforced composite can be attributed to clustering of nanoclay or to occasional occurrence of micro size voids in microstructure, especially at the inter phase of nanoclay and matrix in this work we also did the testing of XRD, SEM, Tensile and bending and we got the result of these with different parameter.
2. The tensile strength is raised by 36% by using the modified epoxy. The maximum value of tensile strength is achieved by the using 3% of clay in the epoxy and further addition causes the reduction in the strength. The stress concentration is reason for the reduction in the tensile strength which is due to agglomerates as visible in the SEM images.
3. The percentage weight gain was highest in the case of neat epoxy it was 4.1% but it was less when epoxy was modified with nanoclay.
4. There were small voids or bubbles visible in SEM images at nano level as these cracks propagates during testing and can produce failure, which can be avoided by using ice cold water during sonication in ultrasonicator bath.
5. The clay clusters were formed and it was also adhering to the beaker as well as spatula before adding to base epoxy to avoid this clay should be heated for some time to remove any sort of moisture present in it. This can further help in better dispersion of nanoclay particles in epoxy.

9.2 FUTURE SCOPE

1. Wear properties can also be ascertained.
2. Work should incorporate evaluation of FRP composite material when exposed across New Zealand over multi years periods.

3. Experiments can be repeated by changing the type of nanofillers.
4. The experimental results of sandwich structure can be validated by using modelling and analysis.
5. PVC foam with different thicknesses can be studied.
6. Alkaline aqueous solution can be taken in spite of water environment for study.

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