ENHANCEMENT OF MECHANICAL PROPERTIES BY IMPREGNATED MONTMORILLONITE EPOXY IN BI-DIRECTIONAL GFRP

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ABSTRACT

Polymer composites are the structural material of high performance and considered as potential which are inherently sensitive to environment. Adding of layered silicate nanofillers in the polymer matrix which can lead to improvement of mechanical properties like tensile strength, flexural and impact strength etc. Composite materials are being increasingly used in various applications like space, aircraft, marine, architectural and automobile sector because of their superior physical and mechanical properties even though they are a little bit costly. In the present work, epoxy was modified with Nanoclay (Montmorillonite) at 0,3,4,5 wt.% of resin and Bi-directional Glass Fibers are used to prepare fiber reinforced nanocomposites using Vacuum bag moulding for excess resin to be removed. Then, the mechanical properties are measured by carrying tensile test, Flexural, ILSS in Tensometer and Impact test on Izod impact tester. The results are reported for the prepared Bi-directional glass fibers with pure epoxy and Impregnated nanoclay epoxy and presented the conclusion.

Index Terms: - Bi-directional glassfiber, Interlaminar shear strength (ILSS), Montmorillonite (MMT), Tensometer, Vacuum Bag Moulding

1. INTRODUCTION

A composite is defined as a combination of two or more materials that results in better properties that are different from the base material. Composites are existing materials, which are finding increasing applications in aerospace and defense where the combination of opposites i.e., lightweight combination with high stiffness is essential. Composites also find their applications in transportation, communication, power, electronics, sporting and numerous and other commercial and consumer products. The potential pay-off for composites materials is so high that they have become one of the fastest development areas of material science. Rapid development in the science of fibers, matrix materials, processing, interface structure, bonding and their characteristics on the final properties of the composites have taken place in the recent years. Recently, there have been more technological developments in composites. The technological developments in composite materials are responsible for partially meeting the global industrial demand for materials with improved performance capabilities.

Layered silicate nanofillers have proved to trigger a tremendous properties improvement of the polymers in which they are dispersed. Amongst those properties, a large increase in moduli of nanocomposites at filler contents sometimes as low as 1wt% has drawn a lot of attention in today's scenario. Finally, depending on the type of polymeric matrix, they display interesting properties on addition of small amounts of nanoclay into fiber reinforced polymer (FRP) system which improve tensile strength and fatigue strength, toughness and impact properties. For manufacturing fiber reinforced polymer nanocomposites, nanoclay is first dispersed into polymer resin using methods such as: in situ polymerization, melt intercalation, solution processing, direct mixing and ultrasonication. The modified polymer matrix is then reinforced with fibers to manufacture fiber nanoclayhybrid composites using different best manufacturing methods.

The main advantages of composite materials are their high strength and stiffness combined with low density when compared to bulk materials, also a lighter weight final product. In most cases, the reinforcement is harder, stronger, and stiffer than the matrix. Vacuum bag moulding is a modification of hand lay-up, in which the lay-up (necessarily smaller) is completed and placed inside a bag made of flexible film and all edges are sealed. The bag is then evacuated, so that the pressure eliminates voids in the laminate, forcing excess air and resin from the mould. By increasing external pressure, a higher glass concentration can be obtained, as well as better adhesion between the layers/plies of laminate.

Vacuum bagging (or vacuum bag laminating) is a clamping method that uses atmospheric pressure to hold the adhesive or term coated components of a lamination in place until the adhesive cures. (when discussing composites, “resin” generally refers to the resin system-mixed or cured resin and hardener-rather than unmixed 105 epoxy resin) modern room-temperature-cure adhesives have helped to make vacuum bag laminating techniques available to average builder by eliminating the need for much of the sophisticated and expensive equipment required for laminating in the past. The effectiveness of vacuum bagging permits the laminating of a wide range of materials from traditional wood veeners to synthetic fibers and core materials.

VACUUM BAGGING EQUIPMENT

The vacuum bagging system consists of the airtight clamping envelope and a method for removing air from the envelope until the epoxy adhesive cures. The components of this system, which include both specialized equipment and commonly available materials.

Peel-ply: a sacrificial open weave fiberglass or perforated heat-set nylon ply placed between the laminate and the bleeder/breather to provide the textured and clean surface necessary for further lamination or secondary bonding.

Bleeder: a non- structural fabric designed to absorb excess resin and reactants from the laminate. This may also act as the breather cloth.

Breather cloth: a loose weave of non-woven porous material use to provide a gas flow path over the laminate both to permit the escape of air, reactants, moisture and volatiles and to ensure uniform vacuum pressure across the component. This may also act as the bleeder cloth.

Release fill: a (perforated) sheet of material placed between the laminate and the mould surfaces to prevent adhesion

Edge dams: profile used to define the edge of the component

Caul plate: a mould or tool placed on top of the laminate inside the bag to define the second surface.

Intensifiers: generally hard rubber profiles incorporated in the bag to consolidate the laminate at sharp radii.

Bagging fill: The membrane which permits a vacuum to be drawn within the bag.

Tacky tape: adhesive strip used to bond the bag to tool and provide a vacuum seal.

Breach unit: a connector through the bagging film to permit a vacuum to be drawn.

Vacuum pipes: The link between the breach unit and the vacuum pump.

Resin trap: a container in the vacuum line to collect any excess resin before it can damage the vacuum pump.

Vacuum pump: generally a high-volume pump (absolute vacuum is rarely reused) suitable for continuous running. For some slow-cutting epoxy resins twenty-four operation may be needed.

Pressure gauges: generally clock-types gauges attached via a breach unit connection.

2. EXPERIMENT

2.1 Materials

In this experiment E-glass bi-directional mat was used as reinforcement because of its high strength, light weight and high chemical resistance and Epoxy resin Araldite LY-556 because of its outstanding physical strength properties for high performance bonding, sealing, coating with Hardener Amine HY-951 are used as matrix. Our polymer composites are formulated to meet challenging physical strength requirements. Nano clay Montmorillonite is incorporated in epoxy resin in different weight percentages (3%, 4%, and 5%) to increase the final Nano composite properties. The pure epoxy, Modified epoxy with three different weight percentages was reinforced into the glass fibers to manufacture the four reinforced polymer nanocomposites.

2.1.1 ***Bi-directional Glass Fiber***

Bi-Directional Fiber glass is of white in colour which is available as dry fiber fabric shown in figure below. And used for structural applications use like fibers or strands of same weight or yield in both warp(longitudinal) and fill(transverse) directions.Glass fiber is one of the most common reinforcing elements used in commercial and industrial composites. Glass fiber has properties such as high strength, flexibility, durability, stability, light-weight, and resistance to heat, temperature, and moisture make glass fiber an essential raw material for GFRP Composites that are used in variety of applications. This fiber composition is of mainly SiO_2(54%), $A1_2O_3$(24%), MgO(10%).

Figure 1 Bi-Directional Fiber

2.1.2 ***Thermosetting (epoxy) resin***

Epoxies are much more expensive than polyester resins because of the high cost of the precursor chemicals most notably epi chloro hydrin. However, the increased complexity of the 'epoxy' polymer chain and the potential for a greater degree of control of the cross linking process gives a much improved matrix in terms of strength and ductility. Epoxy polymers are made by reacting epichlorohydrin with bisphenol-A in an alkaline solution which absorbs the HCl released during the condensation polymerisation reaction. Each chain has a molecular weight between 900 and 3000 with an epoxide grouping at each end of the chain but none within the polymer chain. The epoxy is cured by adding a hardener in equal amounts and being heated to about 120°C. The hardeners are usually short chain diamines such as ethylene diamine. Heat is usually required since the cross linking involves the condensation of water which must be removed in the vapour phase.

Figure 2 EPOXY and HARDNER

2.1.3 ***Hardner***

A substance or mixture added to plastic composition to promote or control the curing action by taking part in it. Also, a substance added to control the degree of hardness of the cured film.

2.1.4 ***Nanoclay (Montmorillonite)***

Montmorillonite is a very soft phyllosilicate group of minerals that typically form in microscopic crystals, forming clay. It is named after Montmorillon in France. Montmorillonite, a member of the smectite family, is a 2:1clay, meaning that it has 2 tetrahedral sheets sandwiching a central octahedral sheet. The particles are plate-shaped with an average diameter of approximately one micrometer. Members of this group include saponite. The water content of MMT is variable and it increases greatly in volume when it absorbs water.

Figure 3. Nanoclay (Montmorillonite)

2.1.5 ***Releasing Agent***

It is used oil obtained from the engine after burn which is used for easily Removal of Specimen from the mould.

2.2 FABRICATION OF COMPOSITES

1. Prepare the materials to be laminated. Cut fabrics, veneers and core materials to shape and place them in a convenient area for wet-out or placement in the mold. Cut the release fabric, perforated film (if required), breather material and vacuum bag to size, then roll or fold them and placed them in a convenient location. Cut the vacuum bag 20% larger than the mold dimensions.
2. Apply the appropriate mold release to the mold and shelf surfaces. Follow the manufacturer’s directions for application. If you are using paste wax buff the last coat so excess wax will not be picked up by the laminate.
3. Apply a coat of gel coat to the mold and allow it to cure. In this example, the gel coat is a mixture of resin/hardener and white pigment, thickened slightly with 406 colloidal silica. It

will provide a good base for paint and help prevent "print-through" of the fabric. Wash the surface of the cured gel coat with water and an abrasive pad to remove any amine blush that may have formed on the cured surface. Dry the surface thoroughly with clean paper towels. Sand bumps or rough areas to assume the laminate will lie flat in the mold.

4. Apply mastic sealant to the mold perimeter. Use firm pressure and overlap the ends so there are no gaps. Leave space around the laminate area and keep the paper backing in place on the mastic so it will not become contaminated with wet epoxy, it is nearly impossible to seal the bag to wet mastic. Apply the appropriate mold release to the mold and shelf surfaces, follow the manufacturer's directions for application. If you are using paste wax buff the last coat so excess wax will not be picked up by the laminate.

5. Place the first layer of two layers of fabric in position in the mold. Once the epoxy is mixed, the time limit for the entire process is established, based on the hardener used, ambient temperature, and the volume of laminate in the mold/ when multiple batches of epoxy are used on larger layups, apply full vacuum pressure before the first mixed batch reaches its initial cure.

6. Squeeze excess epoxy from each layer of fabric after it is wet out. There should be no puddles of epoxy or air pockets under the fabric. Because fabrics are compressed when vacuum bagging, less epoxy is required. Properly wet out fabric may appear drier than for a normal wet lay-up. When properly wet out, a puddle of epoxy will appear around the edges of the thumb print after a few pounds of pressure are applied with a (gloved) thumb.

7. Place a layer of release fabric over the laminate. The release fabric will peel off the cured laminate leaving a fine-textured surface. Excess epoxy which has bled through will be removed along with the release fabric.

8. Place breather material over the release fabric. Breather fabric is a polyester blanket that allows air to pass through its fibers to the port and absorbs excess epoxy that passes through the release fabric. Press all of the layers of material into contact with the mold to avoid "bridging" when vacuum pressure is applied.

9. Place the vacuum bag over the mold and seal it to the mold's perimeter. Starting at a corner of the mold, peel the protective paper from the mastic. Press the edge of the bag firmly onto the mastic while pulling the bag taut enough to avoid wrinkles. When cutting the bag to size, allow enough excess bag material within the sealant perimeter to avoid stretching the bag or bridging areas when the vacuum is applied. It should be at least 20% larger than the mastic perimeter or larger if it is a deep mold.

10. Because the bag perimeter is greater than the sealant perimeter, you should create several folds or pleats of excess material as the bag is sealed around the mold.

11. Seal the pleats of excess bag with a strip of mastic from perimeter mastic to the inside top of the pleat. Then press the bag to both sides of the strip forming a continuous airtight seal. Repeat this procedure wherever there is a pleat around the mold.

12. Connect the vacuum line to the bag with a vacuum port. The vacuum port used here is basically suction cup with a hole through it, attached to the end of the line. Puncture a small hole in the bag and attach the port to the bag over the hole. Breather fabric provides a path to the port inside the bag over wide area. Place an extra layer or two of breather under the port. On smaller molds, place the port outside of the trim line on the mold flange or shelf, multiple ports may be necessary on larger parts.

13. Turn the vacuum pump on, to begin evacuating air from the bag. In necessary, temporarily shut off the vacuum to reposition laminate or adjust the bag.as the air is removed from the bag, listen for leaks around the bag perimeter, especially at folds in the bag, laps in the mastic and at the vacuum line or poor connection. Where leaks are found, push the bag into the sealant or, if necessary, plug the leaks with pieces of mastic or tape.

14. Attach the vacuum gauge to the vacuum bag over a puncture in the vacuum bag. A hissing sound will indicate that enough air is leaking through the puncture to draw a vacuum on the gauge, place the gauge away from the exhaust tube or port connection .most gauges read in inches of mercury.to approximate the reading in psi, divide the gauge reading by two. Allow the laminate to cure thoroughly before turning off the vacuum pump.

15. After the laminate has cured thoroughly, remove the vacuum bag, breather and release fabric. Separate the laminate from the mold by inserting small wooden or plastic wedges between the edge of the laminate and mold.

Insert wedges along one side of the part then insert additional wedges to extend the separate on around the part until it pops loose. After the other half is laminated, trim and bond both halves together.

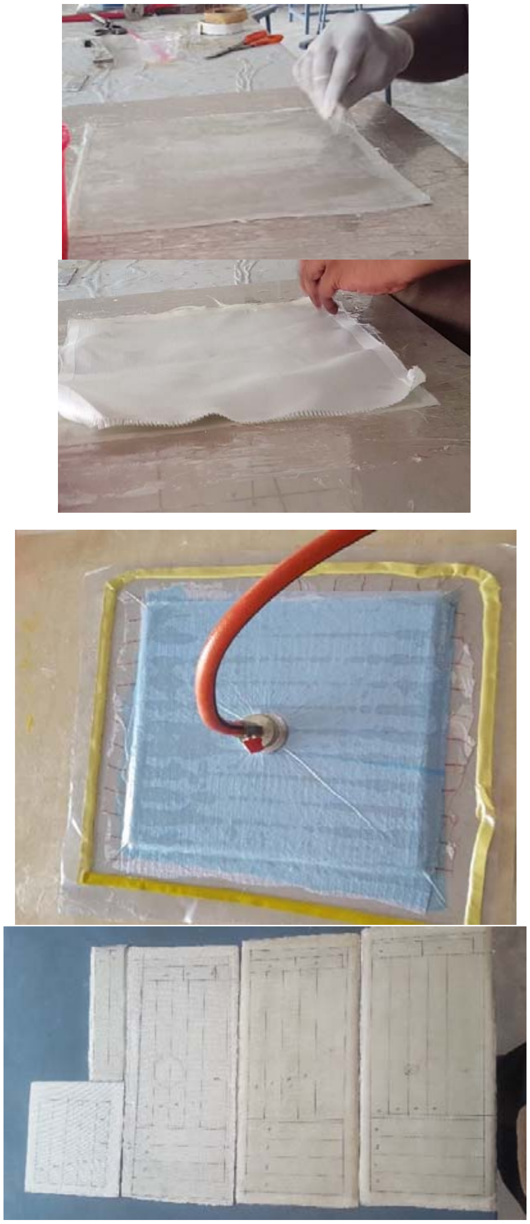


Figure 4. Vacuum Bag Moulding Technique

2.3 Mechanical properties testing of Fabricated Specimen

Tensile test, flexural test, ILSS test is conducted on Tensometer and Impact test on Izod Impact tester were carried out on 16 samples of Bi-directional glass reinforced with Nanoclay for each test which were cut according to the standards.

Figure 5.Tensometer

Figure 6. Izod Impact tester

2.3.1 ***Tensile test***

The 16 samples were tested as per standard of ASTM D638 for different weight percentages of nanoclay impregnated in epoxy 0%,3%,4%,5%(four for each) and the best of four samples for different weight percentage samples are tabulated:

Table 1. Tensile test results

Sam -ple No.	Maximu m Yield Force(N)	Tenile strength at Yield (Mpa)	Tensile strengt h at Break (Mpa)
0%	5845	97.4	99.6
3%	7103	111.6	114.1
4%	7916	119	122.7
5%	9683	124.7	128.4

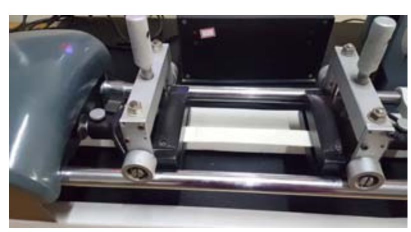


Figure 7. Tensile Specimen

2.3.2 ***Flexural test***

The 16 samples were tested as per standard of ASTM D790 for different weight percentages of nanoclay impregnated in epoxy 0%,3%,4%,5%(four for each) and the best of four samples for different weight percentage samples are tabulated:

Table 2. Flexural test results

Specimen Name & No.	Yield Force(N)	Flexural Strength(MPa)
0%	88.3	2.45
3%	122.8	3.41
4%	176.5	4.91
5%	229	6.37

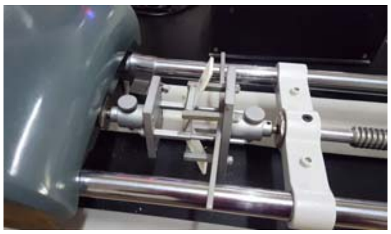


Figure 8. Flexural specimen

2.3.3 ***ILSS test***

The 16 samples were tested as per standard of ASTM D2344 for different weight percentages of Nanoclay impregnated in epoxy 0%,3%,4%,5%(four for each) and the best of four samples for different weight percentage samples are tabulated:

Table 3. ILSS test results

Specimen Name & No.	Yield Force(N)	Interlaminar Shear Strength(MPa)
0%	98.9	2.15
3%	198.32	4.28
4%	253.56	5.48
5%	190.86	4.12

Figure 9. ILSS grippers

2.3.4 ***Impact test***

The 8 samples were tested as per standard of ASTM D256 for different weight percentages of nanoclay impregnated in epoxy 0%,3%,4%,5% (four for each) and the best of two samples for different weight percentage samples are tabulated

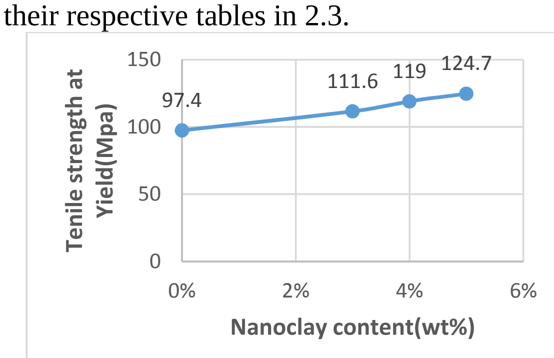
Table 4. Impact test results

Specimen Name & No.	Work Done (J)	Impact Strength (J/M)
0%	3.82	374.5
3%	4.63	451.7
4%	6.31	608.7
5%	5.6	568.5

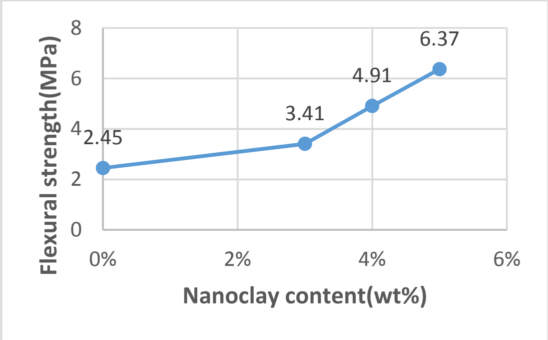
Figure 10. Tested specimens

3. RESULTS AND DISCUSSION

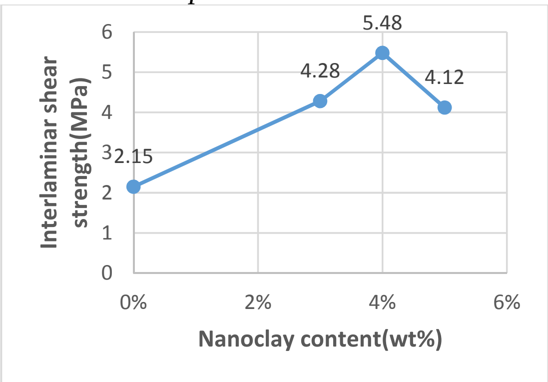
The Fabricated samples have been tested on Tensometer as per ASTM(American Society for Testing and Materials) to find the values of yield forces for all tests done,also tensile strength at yield and break, flexural strength, and interlaminar shear strength. The Impact test was also carried I-Zod impact tester to get the work done which impact strength is calculated. It may be noted that the tests are successfully done as fracture is obtained at the center of the tested samples. The calculated values are also kept in their respective tables in 2.3.



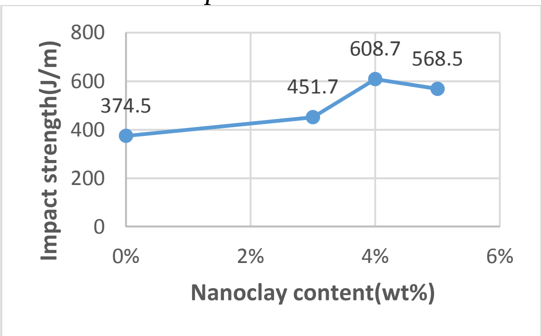
Graph 1 Tensile test



Graph 2. Flexural test



Graph 3. ILSS test



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Graph 4. Impact test

The result of different values of tensile, flexural, ILS, impact strength are kept on a graph 1,2,3,4 which shows the values at different weight percentages of nanoclay Impregnated epoxy fabricated glass composite.

4. CONCLUSION

In all the testing of properties of tensile, flexural, ILSS and Impact strength on fabricated Nanoclay impregnated epoxy glass fiber composite. The following points have been concluded

- In tensile test, the yield force has been increasing with addition of nanoclay upto %5 for the samples tested which means that the tensile strength has been increasing. So, it tells that Nanoclay impregnated epoxy glass fiber composite (%5) has more tensile strength.
- In Flexural test, the yield force is similarly increasing with addition of nanoclay %5 for the samples tested which means that the tensile strength has been increasing which tells that Nanoclay impregnated epoxy glass fiber composite (%5) has more Flexural strength.
- In ILSS test, it is similar to flexural but a change in dimensions of specimen which also showed that Nanoclay impregnated epoxy glass fiber composite (%4) has more strength where yield was force was increasing upto %4 and showed a decrease in %5.
- In Impact test, the work done is increasing upto %4 upto which impact strength was increased and decreasing afterwards.
- Better intercalation of nanoclay in epoxy was observed more in 3% and 4% rather than %5 weight mixture in epoxy.

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