

Mechanical Behavior and Dynamic Mechanical Analysis Study on Nanoclay Filled Carbon-Epoxy Composites

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ABSTRACT: In this project the effect of Nanoclay filler on mechanical properties of carbon fiber reinforced epoxy resin composites is investigated. Carbon fiber is one of the most useful reinforcement materials in composites, its major use being the manufacture of components in the aerospace, automotive industries. Carbon fabric reinforced epoxy (C-E) composites filled with different weight proportions of Nanoclay were fabricated by using hand layup technique. The filler Materials added to the matrix is to improving operating properties of a composite. This experimental study has targeted to study on Mechanical behavior and the wear properties of carbon-epoxy composite. In CFRP composite filled with Nanoclay in the range of 2.5%, 5% and 10% with the matrix. After the fabrication work, Flexural and Impact testing is carried out with use of ASTM standard machines for investigate the mechanical behavior of the Carbon fabric reinforced epoxy (C-E) composites. And the dynamic mechanical analysis is carried out to find storage modulus, loss modulus, glass transition temperature and ten deltas. Among the selected composites 2.5 % nanoclay filled C+E composite exhibits better mechanical properties.

KEYWORDS: Carbon fabric reinforced epoxy, Nanoclay ASTM standard,

I.INTRODUCTION

A composite material is made by combining two or more materials to give a unique combination of properties. The above definition is more general and can include metals alloys, plastic co-polymers, minerals, and wood. Fiber-reinforced composite materials differ from the above materials in that the constituent materials are different at the molecular level and are mechanically separable. In bulk form, the constituent materials work together but remain in their original forms. The final properties of composite materials are better than constituent material properties. The concept of composites was not invented by human beings; it is found in nature. An example is wood, which is a composite of cellulose fibers in a matrix of natural glue called lignin. The shell of invertebrates, such as snails and oysters, is an example of a composite. Such shells are stronger and tougher than man-made advanced composites. Scientists have found that the fibers taken from a spider's web are stronger than synthetic fibers. In India, Greece, and other countries, husks or straws mixed with clay have been used to build houses for several hundred years. Mixing husk or sawdust in a clay is an example of a particulate composite and mixing straws in clay is an example of a short-fiber composite. These reinforcements are done to improve performance.

II. GEOMETRICAL CONFIGURATIONS

Carbon-fiber-reinforced polymer, carbon-fiber-reinforced plastic or carbon-fiber reinforced thermoplastic (CFRP, CRP, CFRTP or often simply carbon fiber, or even carbon), is an extremely strong and light fiber-reinforced polymer which contains carbon fibers. The binding polymer is often a thermoset resin such as epoxy, but other thermoset or thermoplastic polymers, such as polyester, vinyl ester or nylon, are sometimes used. The composite may contain other fibers, such as aramid e.g. Kevlar, Twaron, aluminium, or glass fibers, as well as carbon fiber. The properties of the final CFRP product can also be affected by the type of additives introduced to the binding matrix (the resin). The most frequent additive is silica, but other additives such as rubber and carbon nano tubes can be used. CFRPs are commonly used in the transportation industry; normally in cars, boats and trains, and in sporting goods industry for manufacture of bicycles, bicycle components, golfing equipment and fishing rods. Although carbon fiber can be relatively expensive, it has many applications in aerospace and automotive fields, such as Formula One racing and wherever high strength-to-weight ratio and rigidity are required such as sailing boats and rowing shell hulls, top-end bicycles and motorcycles, As manufacturing techniques improve and costs reduce it is becoming increasingly common in small consumer goods that require strength, lightness and stiffness such as: laptop bodies.

In this design part the following polymer reinforced composites are chosen.

- Fiber : Carbon
- Matrix : Epoxy
- Filler : Nanoclay

NAME OF THE COMPOSITE	CARBON percentage	EPOXY percentage	NANOCLAY Percentage
Carbon + Epoxy	60	40	-
Carbon + 2.5 Epoxy	60	37.5	2.5
Carbon + 5 Epoxy	60	35	5
Carbon + 10 Epoxy	60	30	10

Table 1 Weight % of Nanoclay



Figure 1 Specimen in Weight % of Nanoclay

III. TESTING

After fabrication work mechanical behavior and dynamics mechanical analysis is carried out. In mechanical behavior test the following three tests is conducted

- Tensile test
- Flexural test
- Impact test

TENSILE TEST

The tension test is the most common method for determining the mechanical properties of materials, such as strength, ductility, toughness, elastic modulus, and strain hardening capability. The tension test first requires the preparation of a test specimen. Although most tension-test specimens are solid and round, they can also be flat or tubular. The specimen is prepared generally according to ASTM specifications; various other specifications are also available from corresponding organizations around the world. The tensile behavior of prepared samples was determined at room temperature using Universal testing machine in accordance with ASTM D 3039. Test specimens having dimension of length 250 mm, width of 20 mm and thickness of 2.5 mm. The specimen was loaded between two manually adjustable grips of a 100 KN computerized universal testing machine (UTM) with an electronic extensometer. Each test was repeated thrice and the average value was taken to calculate the tensile strength of the composites.

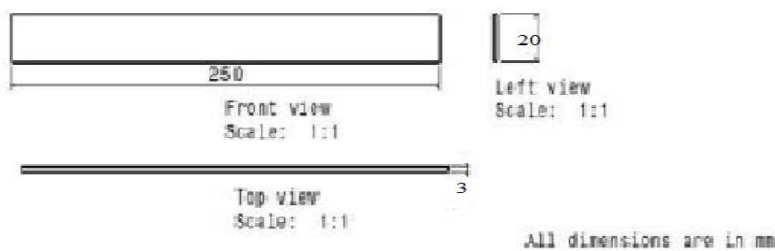


Figure 2 Specimen Size for Tensile Test



Figure 3 UNIVERSAL TESTING MACHINE

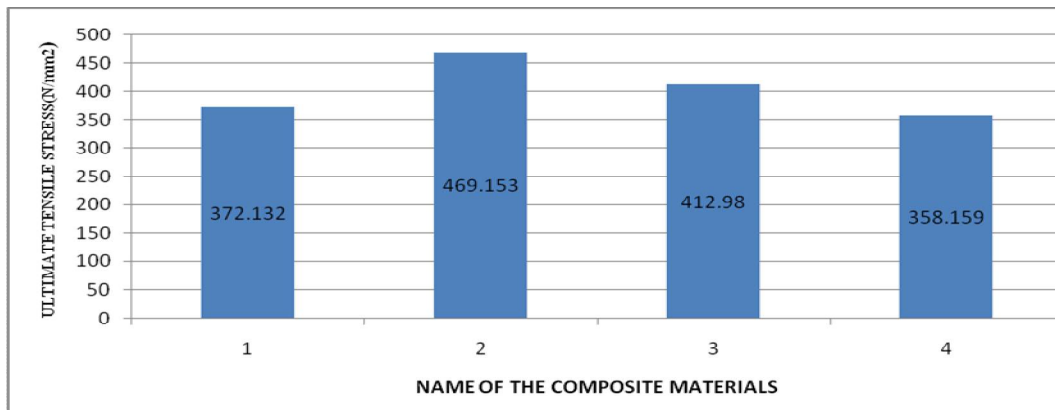


Figure 4 VARIANCES IN UTS

FLEXURAL TEST

Flexural strength is determined by 3-point bend test. The test specimen of dimension 130 mm × 13mm × 3 mm were used for test. This test method determines the flexural properties of fiber reinforced polymer composites. Flexural strength is calculated by the following equation from the standard ASTM D 790

$$\sigma_f = \frac{3PL}{2bh^2}$$

Where:

- σ_f = Stress in the outer fibers at midpoint (MPa)
- P = Load at a given point on the load-deflection curve (N)
- L = Support span, (mm) b = Width of beam tested, (mm)
- h = Depth of beam tested, (mm)

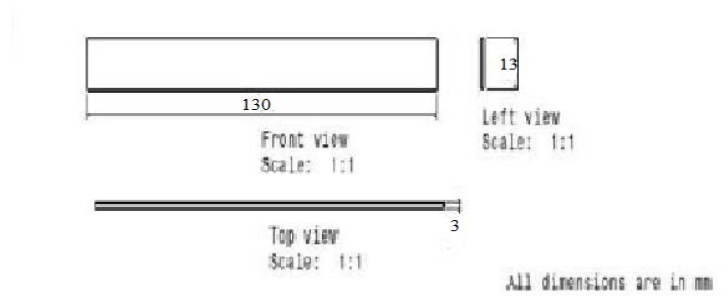


Figure 5 Specimen Size for flexural test

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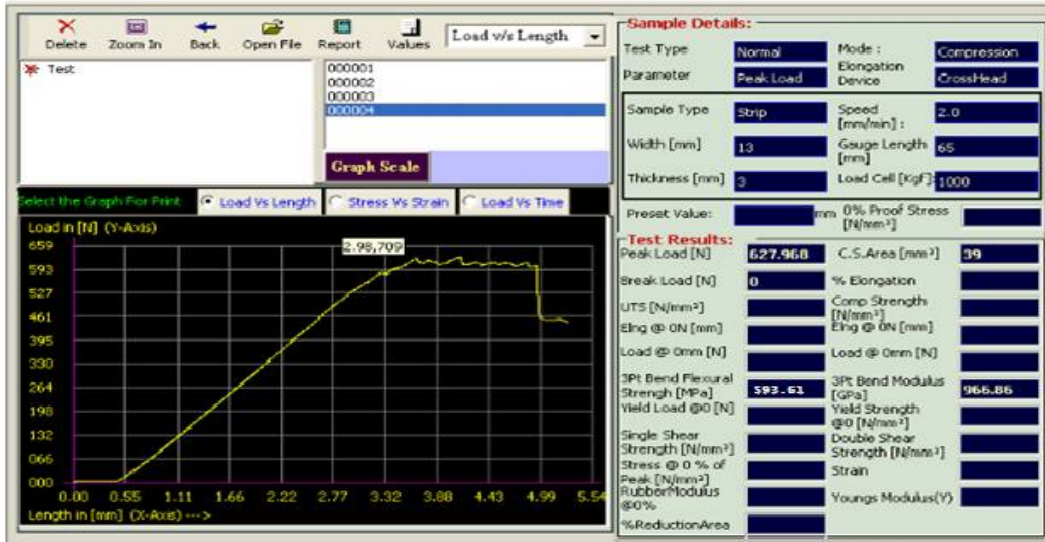


Figure 6 Load vs. % of Elongation for 10 % of Nanoclay

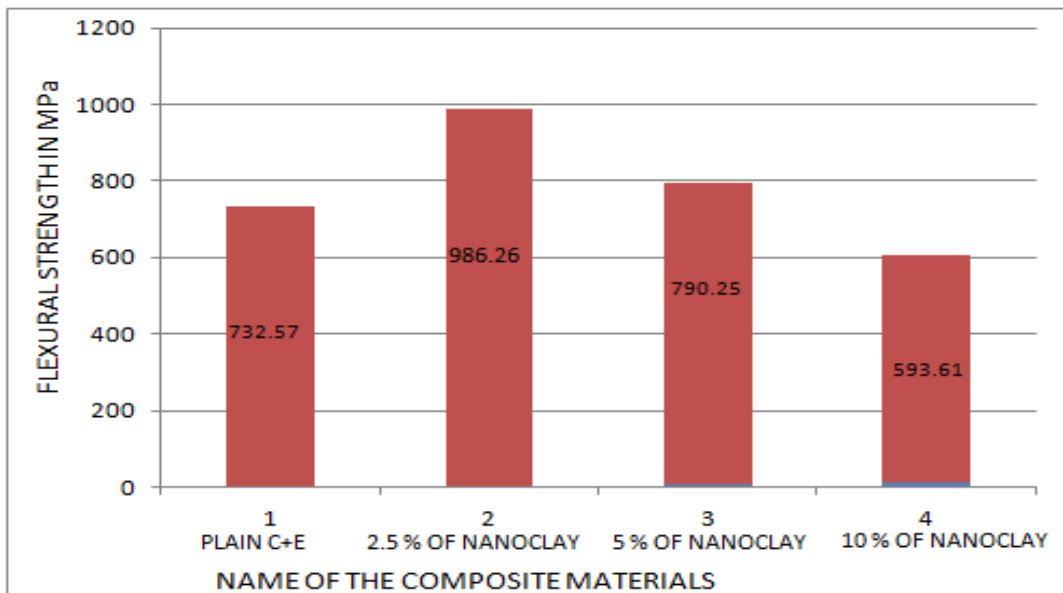


Figure 7 VARIANCES IN FLEXURAL STRENGTH

From the above result we find out flexural strength of 2.5 % of nanoclay filled carbon epoxy composite material is higher than plain carbon epoxy composite material and the 5 % nanoclay filled material is more are same as plain C + E. and 10 % of nanoclay filled material flexural strength decreased than the plain carbon epoxy.

The 2.5 % nanoclay filled composite materials has the higher flexural strength than the another three composite materials.

- Nanoclay is mixed with fiber and matrix material and improves the bonding strength.
- Nanoclay Improving mechanical properties.

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- Improved ILSS due to addition of Nanoclay.

IMPACT TEST

The izod impact strength of composites was tested using a standard impact machine as per ASTM D 256 standard. The standard test specimen 55mm x 13mm x 3mm cross section.

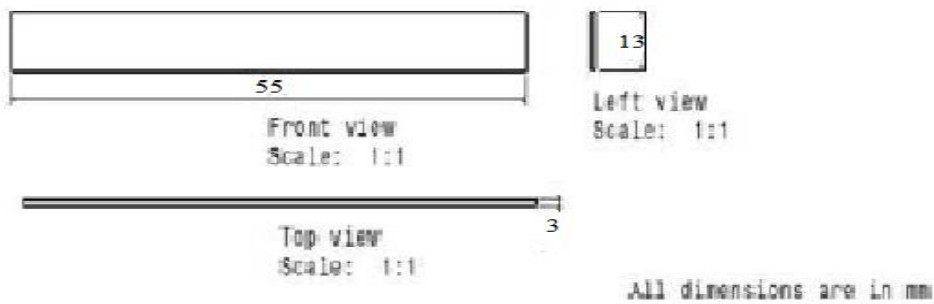


Figure 8 SPECIMEN SIZE FOR THE IMPACT TEST

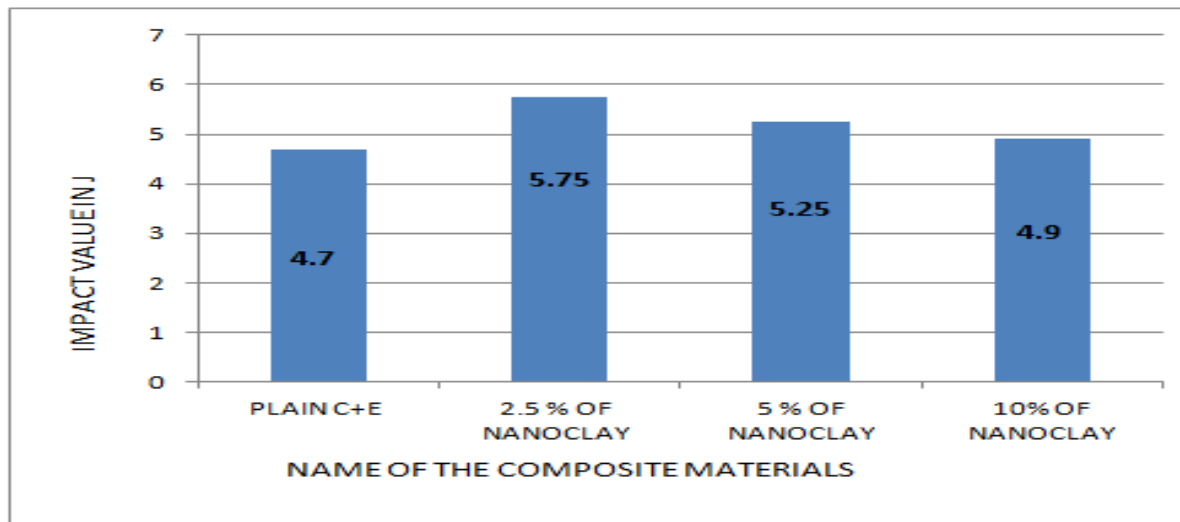


Figure 9 VARIANCES IN IMPACT VALUE

Test Report

Sl.No.	Sample Number	Impact Value for Given Sample in J
1	I ₁	4.70
2	I ₂	5.75
3	I ₃	5.25
4	I ₄	4.90

Table 2 IMPACT RESULT

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From the above result we find out impact load of 2.5 % of nanoclay filled carbon epoxy composite material is higher than plain carbon epoxy composite material and the 5 % nanoclay filled material is more are same as plain C + E. and 10 % of nanoclay filled material impact load decreased than the plain carbon epoxy.

The 2.5 % nanoclay filled composite materials has higher flexural strength than the another three composite materials.

- Nanoclay is mixed with fiber and matrix material and improves the bonding strength.
- Nanoclay Improving mechanical properties.
- Improved ILSS due to addition of Nanoclay.

IV. DYNAMIC MECHANICAL ANALYSIS TEST

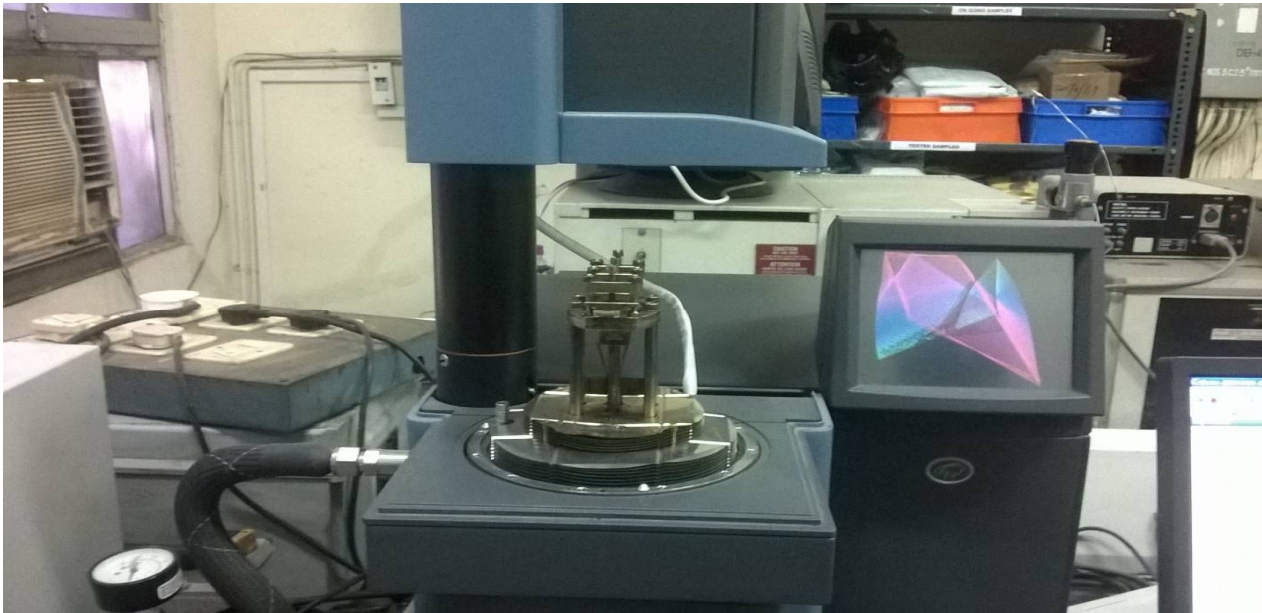


Figure 10 DMA TEST APPARATUS

DMA was carried out as per the standard ASTM D4065-01 using test setup DMA Q800 V 20.6 (TA Instruments, USA). DMA 800 is a controlled stress with combined motor and transducer machine in which motor applies force and displacement sensor measures strain. The signals of force and amplitude were recorded by the machine and the stiffness is obtained from force and amplitude. The storage modulus is obtained using the stiffness data. The DMA instrument was operated in the single cantilever clamp mode which is used to test the nanoclay-filled C-E samples. DMA instrument operates with the frequency of 1HZ. The test was performed in the temperature range from 25 C to 250 C and with the temperature ramp of 2 C/ min. From each material, three samples were prepared with the size of 65mm x 15mm x 3mm using the diamond tipped cutter. The DMA test was conducted for all samples the storage modulus, loss modulus and glass transition temperatures were recorded and revealed.

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Figure 11 DMA TEST APPARATUS

RESULT AND DISCUSSION

STORAGE MODULUS

Storage modulus represents the stiffness of a viscoelastic material and is proportional to the energy stored during a loading cycle. It is roughly equal to the elastic modulus for a single, rapid stress at low load and reversible deformation, and is thus largely equivalent.

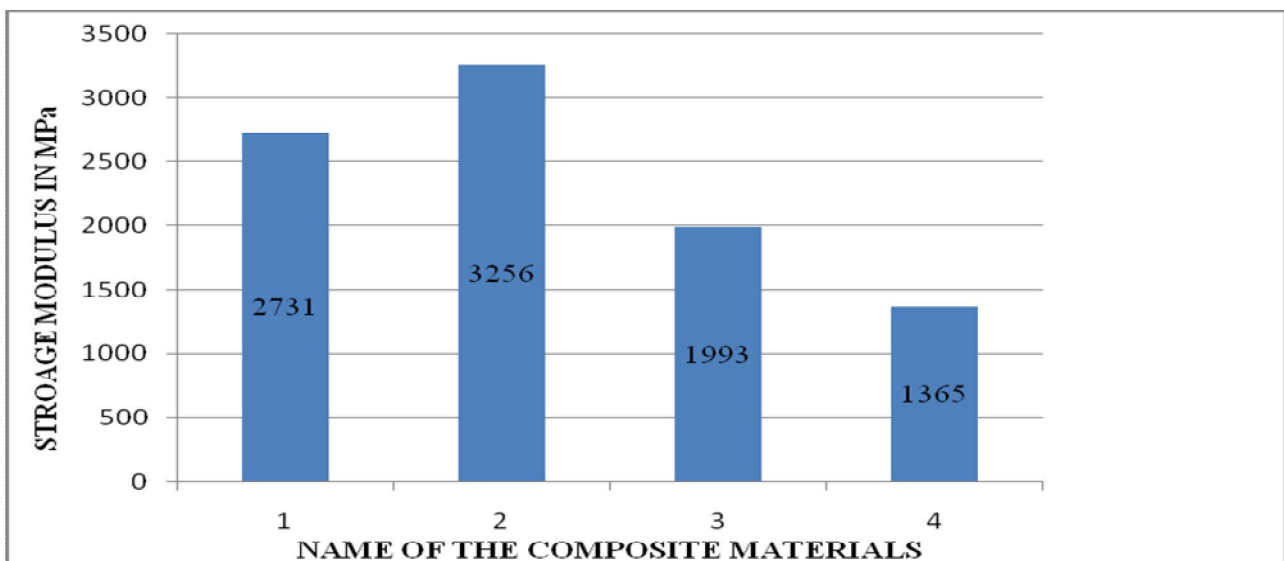


Figure 12 Variances in Storage Modulus

LOSS MODULUS

Loss modulus is defined as being proportional to the energy dissipated during one loading cycle. It represents, for example, energy lost as heat, and is a measure of vibration energy that has been converted during vibration and that

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cannot be recovered. Modulus values are expressed in MPa, but N/mm² are sometimes used. The real part of the modulus may be used for assessing the elastic properties, and the imaginary part for the viscous properties.

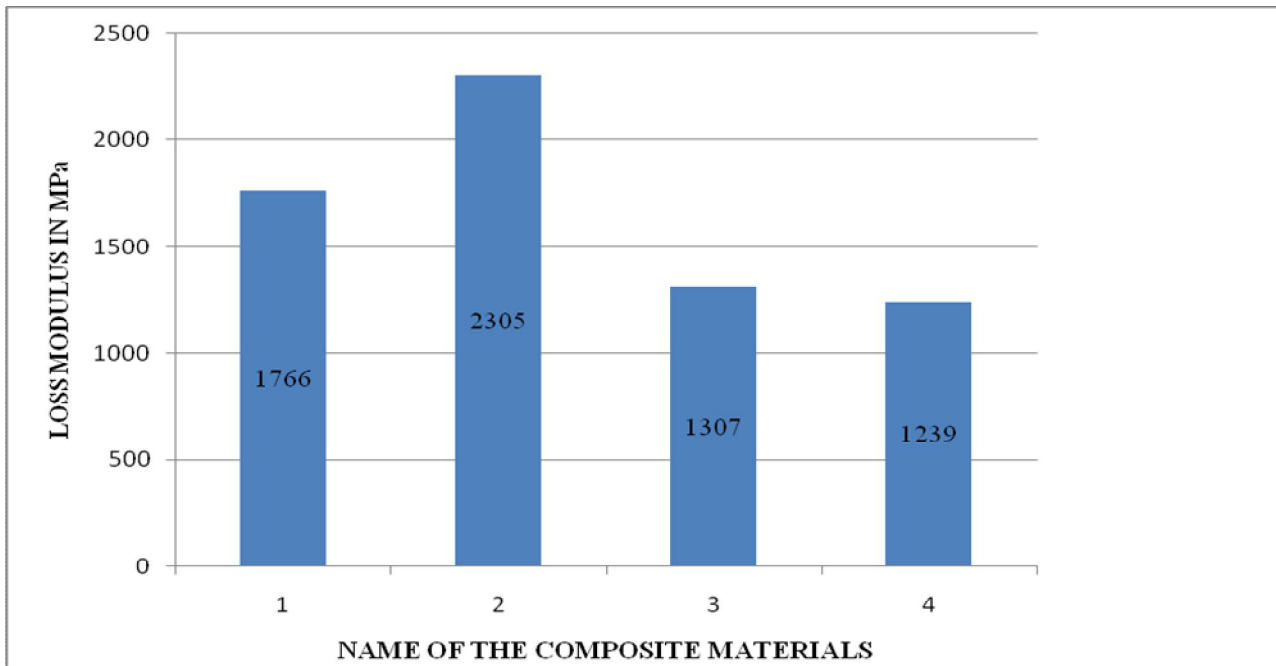


Figure 13 Variances in Loss Modulus

TAN DELTA

The loss factor $\tan \delta$ is the ratio of loss modulus to storage modulus. It is a measure of the energy lost, expressed in terms of the recoverable energy, and represents mechanical damping or internal friction in a viscoelastic system. The loss factor $\tan \delta$ is expressed as a dimensionless number. A high $\tan \delta$ value is indicative of a material that has a high, nonelastic strain component, while a low value indicates one that is more elastic.

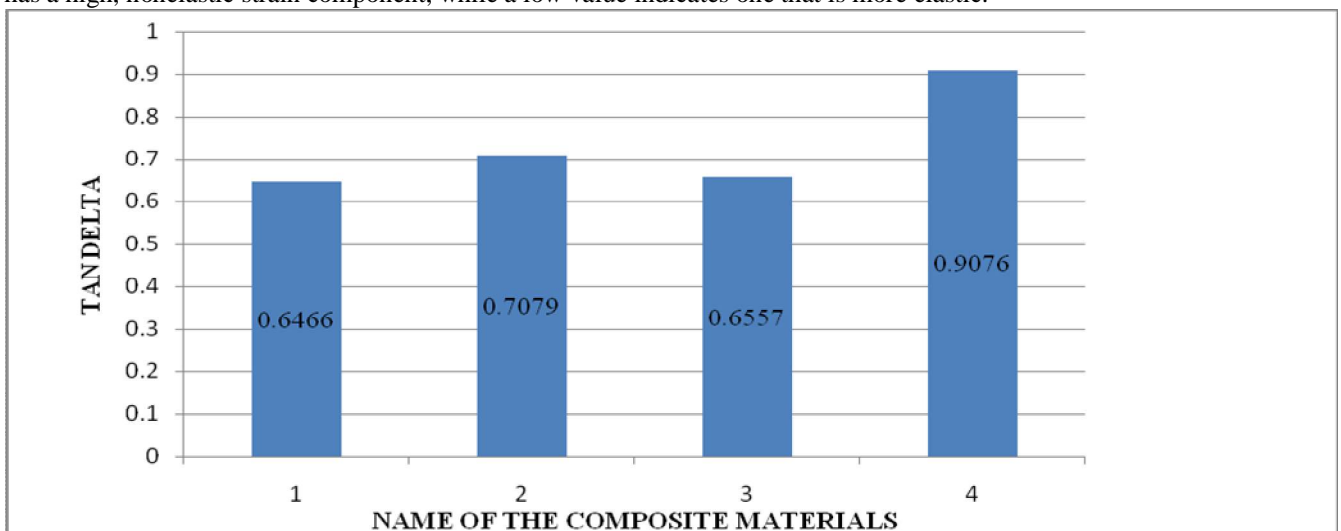


Figure 14 Variances in tan delta

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GLASS TRANSITION TEMPERATURE

One of the most important properties that define a polymer (and hence to an adhesive) is its glass transition temperature, the value of the glass transition temperature is directly related to the mechanical properties (strength, hardness, brittleness, elongation...) that the polymer (adhesive/plastic) presents at the temperature that is exposed, you've never seen in winter why some plastics become hard and brittle?, the explanation lies in its glass transition temperature. Glass transition temperature (T_g) is defined as the temperature at which the mechanical properties of a plastic / adhesive radically changed due to the internal movement of the polymer chains that form the plastic / adhesive. The (T_g) identified as the temperature at which the mechanical properties of the adhesive change drastically, so the glass transition temperature indirectly define the temperature range in which it can be exposed or work the adhesive / plastic, so the T_g is also known as the working temperature and the knowledge of its value is of vital importance in the design phase.

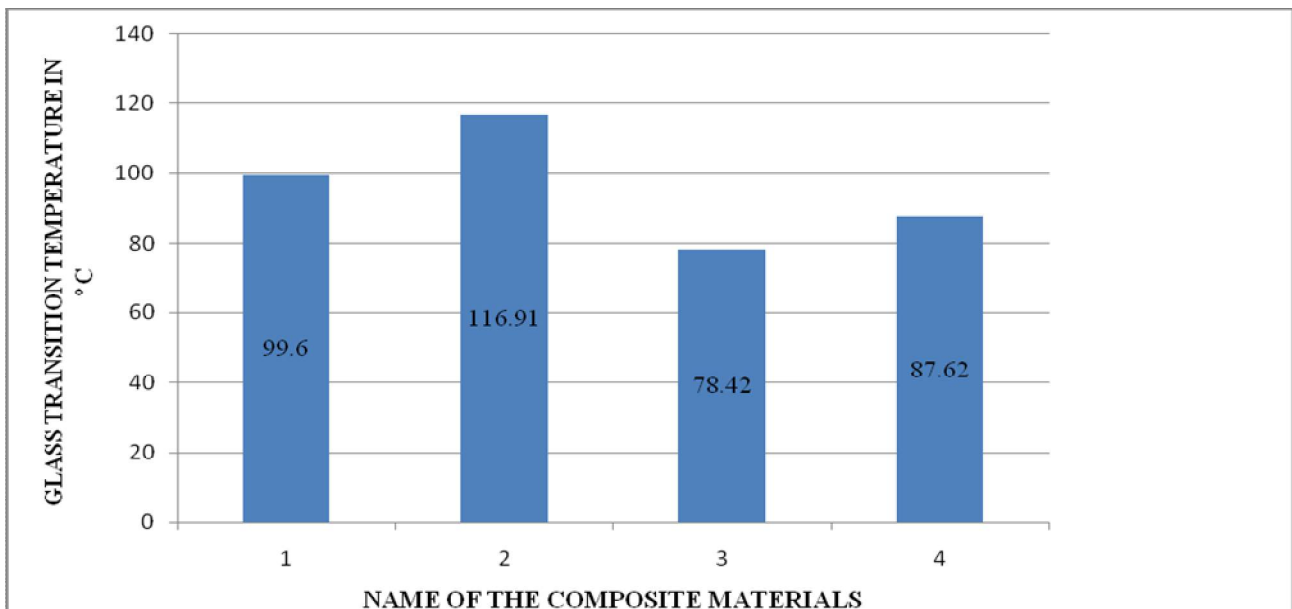


Figure 15 Variances in Glass Transition Temperature •C

From the above result we find out storage modulus and glass transition temperature of 2.5 % of nanoclay filled carbon epoxy composite material is higher than plain carbon epoxy composite material. And the 5% and 10% nanoclay filled material has a low storage modulus and glass transition temperature.

V. CONCLUSION

Based on the analysis of experimental results and findings, the following conclusions can be drawn: This work shows that successful fabrication of a multi component hybrid composite (using epoxy as matrix, continuous carbon fiber as reinforcement and Nanoclay as filler material) was possible by simple hand lay-up technique. Incorporation of these fillers modifies the mechanical properties of the composites Flexural strength and Impact property was noticed in the filled composites where as the presence of these filler Nanoclay has caused in flexural test is to improve the flexural strength in 2.5% and 5% of filler content. In the Impact test the impact energy is also increased in 2.5 % and 10% of filler content. From the DMA test 2.5 % of Nanoclay filled composite material is shows the improvement in storage modulus and glass transition temperature. Finally we find that the Carbon-Epoxy 2.5 % of Nanoclay filled composite material can use the replacement materials for plain carbon-epoxy because it has the higher Flexural strength, Impact energy, storage modulus and glass transition temperature.

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