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Experimental Investigation on Flexural and Vibrational Properties of E-Glass/Epoxy/MWCNTs Reinforced Nano composites

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Abstract: Carbon nanotubes (CNTs), due to their superlative mechanical and physical properties, have shown a high potential to improve the properties of polymeric composites. Adding CNTs into polymers at very low weight fractions can improve mechanical properties of the nanocomposites. In the present work multi-walled carbon nanotubes (MWCNTs) at different weight percentages of 0.4,0.8,1.2,1.6 and 2 were added to epoxy resin along with E-Glass fibre. The nanocomposites prepared by in situ polymerization process then tested for their flexural & vibration properties. Improvements in flexural modulus and stiffness were observed with increase in weight percentage of composites and the highest values were obtained for sample with 1.6 weight percentage of MWCNTs.
Keywords: Multi walled carbon nanotubes , Epoxy resin, E-Glass fibre, , flexural strength, stiffness.

I. INTRODUCTION

CNT is a cylindrical rolled up sheet of graphene, which is a single layer of graphite atoms arranged in a hexagonal shape with each carbon atom covalently bonded to three other carbon atoms[1]. Depending on folding of graphite sheet, they are identified as armchair, zig zag or chiral type nanotubes. The diameter of a nanotube is on the order of nanometres, many times smaller than the width of a human hair, but up to several microns .CNTs have been intensively studied in both fundamental and applied research fields for over one decade [2].Due to their superior mechanical, thermal and electrical properties of MWCNTs ,they are widely used as reinforcement of polymer composites[3-5]. And also because of its low cost and mass production compared to single walled carbon nanotubes, the multi-walled carbon nanotube (MWCNT) deserves special attention[6].

Epoxy resins are commonly used as the matrix of adhesives and composites[7]. The epoxy networks are having applications in the aerospace, electronics and the other fields due to their outstanding mechanical strength, electrical insulation, and chemical resistance[8].Due to the low density of MWCNTs, its combination with E-glass/epoxy laminates results in light weight structures with enhanced mechanical properties[9].

In this present work, we have employed MWCNTs to reinforce the E-glass /epoxy composites with different weight fractions. Samples were fabricated by the *in situ* polymerization process and tested for flexural and vibration properties.

II. EXPERIMENTATION

A. Materials

The materials used for this work ,MWCNTs are of diameter 10-25nm and length 3-8 µm with 99% purity, which was confirmed by the SEM image shown in Fig. 1. Epoxy Resin(LY556) and Finehard 5200 are used as matrix and hardener. E-glass bidirectional fibres are having an aerial weight of 400gsm used to ensure the mechanical strength of the prepared composites.

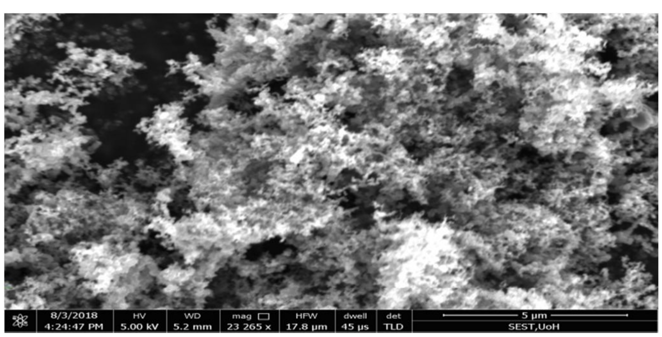

Fig. 1 SEM image of MWCNTs

B. Preparation of E-Glass/Epoxy/MWCNT Composites

By measuring required amounts of epoxy and MWXNTs, they are first mixed with acetone to reduce the viscosity of epoxy. As the MWCNT'S are agglomerate in nature and mechanical mixer was used to mix MWCNT'S thoroughly with epoxy resin for 30 minutes with the speed 500 RPM for uniform dispersion of MWCNT'S with epoxy resin.

The hardener is added to the mixture in the ratio of 100:24 and mix for another 5 minutes at a speed of 200 RPM. By using the hand layup method, coating this prepared mixer on E-glass fibre, six composite specimens were fabricated with MWCNTs in different proportions as 0.4,0.8,1.2,1.6,2 & one pure epoxy sample for reference. The fabrication process was shown in Fig. 2.Placing the specimens in hot air oven for 6 hours at different elevated temperatures, completes the polymerization process.

Fig. 2 Fabrication process of E-glass/epoxy/MWCNT laminates

C. Testing

The fabricated samples were tested for flexural properties on an UTM and the stiffness values were determined by FFT analyzer according to ASTM standards.

III.RESULTS AND DISCUSSIONS

A. Flexural Properties

Flexural test was performed for evaluation of flexural strength of the material. Flexural tests were conducted on a universal testing machine in accordance with ASTM D-790 Standard. specimens of 125mm length, 127mm breadth and 3.2mm thickness were cut and tested as shown in Fig. 3.

Flexural Strength was calculated by this equation (1)

$$\sigma = \frac{3FL}{2bd^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,
F = Break load
L = Support span
B = Specimen width

It is defined as the maximum bending stress that can be applied to that material before it yields. Flexural strength is also known as bending strength.

Fig. 3 Flexural Testing of samples

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Table 1 Flexural Strength Of The Samples

Sample no.	Wt %	Mass (gm)	Flexural strength(N/mm^2)
1.	0.4	25.1	343
2.	0.8	28.04	390.72
3.	1.2	29.45	420.67
4.	1.6	30.17	575
5.	2.0	24.16	557
6.	Pure Epoxy	20.17	233.88

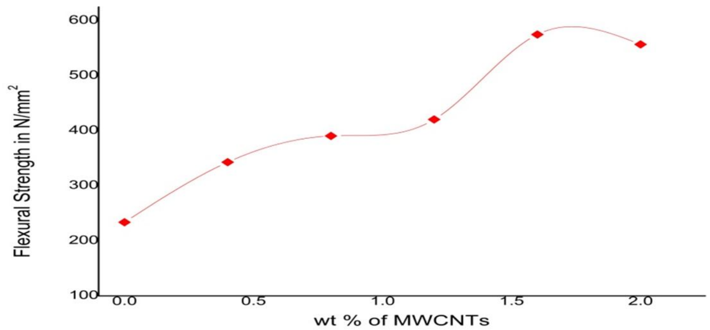

Fig. 4 Variation of Flexural Strength with wt % of MWCNTs

The pure epoxy sample without the addition of the MWCNTs has shown the lowest flexural strength of 233.88 N/mm^2 as shown in the Fig.4. And the flexural strength of the samples increases with increasing the weight percentage of the MWCNTs . The sample number 4 with 1.6 % of filler has shown highest flexural strength of 575 N/mm^2. Compared to the sample 4 ,sample 5 has lower value of strength due to increase in the agglomeration of MWCNTs beyond 1.6%.

B. Vibration properties

The MWCNT/epoxy composite Specimen was cut into beams and tested according to ASTM E-756-05 specification for vibration measurements. The test piece was cut into length of 13 cm length and 1.5 cm width. Vibration testing machine is used to measure the frequencies. The Speicemen was fixed to the vibration testing machine at the edge as a cantilever beam and connected the hammer sensor to the edge of the beam . By striking the beam with the hammer , frequencies were calculated with the data obtained by the analyzer as shown in Fig.5. The stiffness values were estimated by eq (2).

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

f= frequency in Hz; k=stiffness in N/m; m=mass in kg

Fig. 5 FFT Analyzer

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TABLE 2 Stiffness Of The Samples

Sample no.	Wt %	Mass (gm)	Stiffness (N/m)
1	0.4	25.10	1038.71
2	0.8	28.04	1108.02
3	1.2	29.45	1145.88
4	1.6	30.17	1191.47
5	2	24.16	950.50
6	Pure epoxy	20.17	785.43

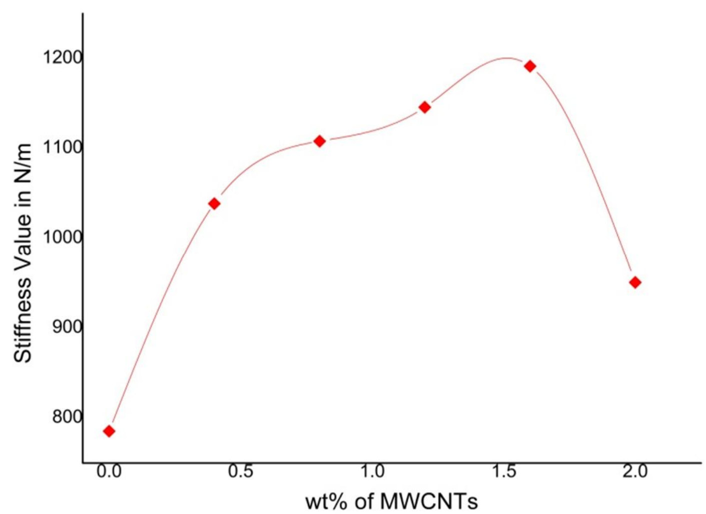

Fig. 6 Variation of Stiffness with wt % of MWCNT

The stiffness properties of the fabricated samples with different weight fractions of MWCNTs were as shown in Fig.6. variation in the stiffness is similar to the variation of flexural strength as both are indicating strength of the composites. The highest stiffness is obtained for sample 4 with a value of 1191 N/m which has 1.6% of MWCNTs.

IV. CONCLUSIONS

In this paper mechanical properties of E-glass/epoxy/ MWCNT nanocomposites at different weight ratios of nanotubes (0.4,0.8,1.2,1.6, 2 & pure epoxy resin) were investigated. Results of flexural and vibration properties demonstrated that MWCNT'S were well dispersed in the epoxy resin except 2 weight percentage. Sample no.4 with 1.6% has shown the greater flexural strength of 575.6 N/mm^2 and stiffness of 1191 N/m. From the results it can be concluded that the prepared E-Glass / epoxy laminates with MWCNTs have potential applications where flexural strength & better vibration properties are the main requirements i.e., in the structures with lateral loads.

V. ACKNOWLEDGMENT

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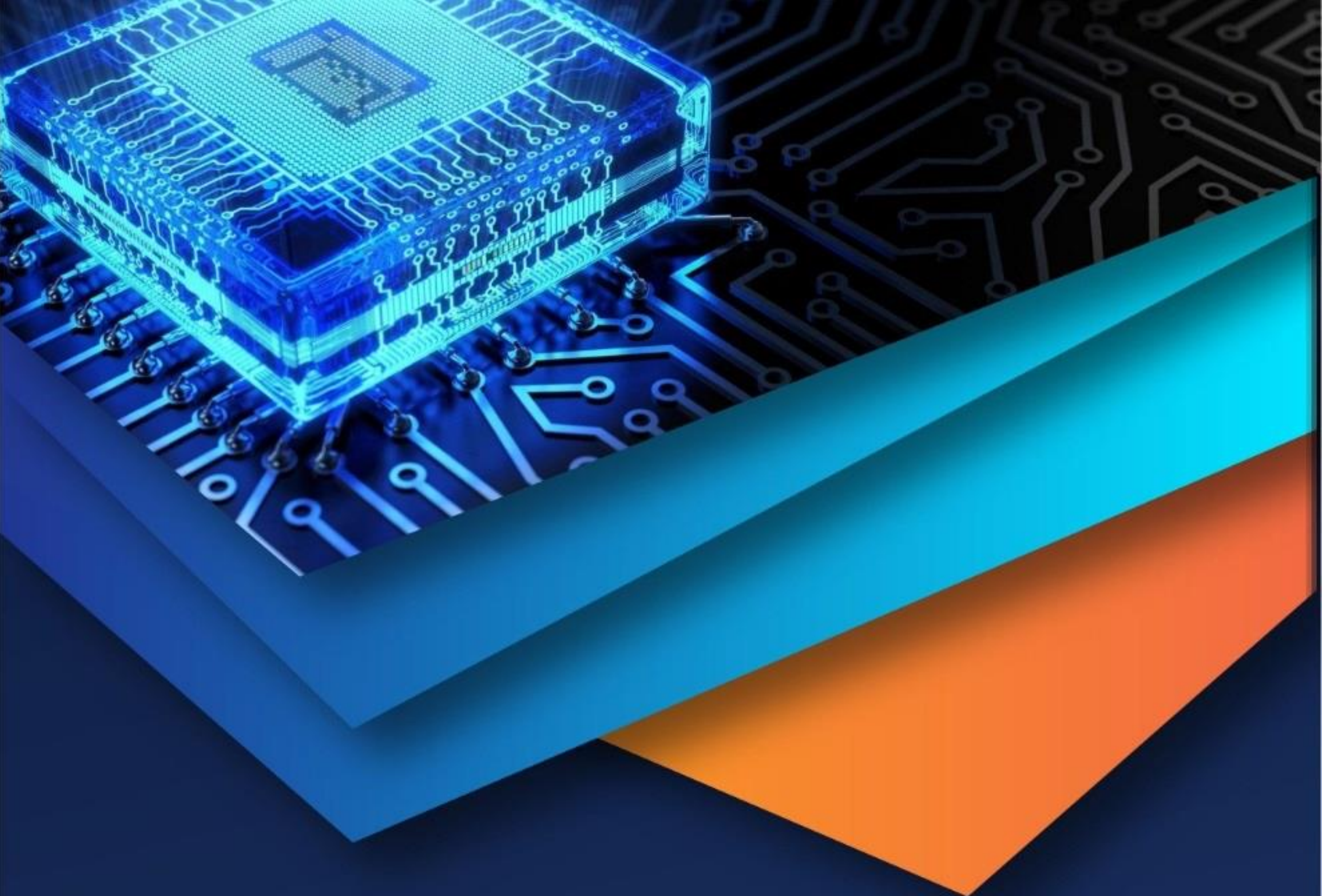

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