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Fracture toughness reinforcement by CNT on G/E/C hybrid composite

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ABSTRACT

There is an enormous application that can be found in the incorporation of CNT for improving properties because of its unique and properties. It is believed that the incorporation of CNT with the hybrid composite moderately increases the strain energy release rate. Hence this piece of investigation focuses on the inclusion of the single wall CNT in Glass/epoxy/carbon hybrid composite. The epoxy used as a matrix phase and the Glass and Carbon woven fibbers used as the reinforcement phase. The mode 1 test employed to investigate the toughness of composites that fabricated with different fashions. In the matrix phase, Carbon Nano Tubes were mixed with epoxy resin in an effort to improve the fracture toughness and it varies from0 to 2 wt% of CNTs. The handy layup technique is used to fabricate the samples. The samples can be characterized by a double cantilever beam test. The result shows that the superior toughening performance of this composite. The toughness of the hybrid composite is enhanced because the extra energy is required to break the CNT for crack propagation in the matrix phase. It is also noted that increasing CNT beyond 1 wt% of CNT'scan be attributed to the slippage among CNT's. It leads to reduce the fracture toughness of the hybrid composite.

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1. Introduction

The composite materials are extensively utilized in a good range of industries including automotive, aerospace, Biomedical, Civil construction, Defence, etc. Hybrid composite is one of the new sort's of the modern composite which has attracted many researchers. Hybrid composite is formed of two or more sorts of fibers within the reinforcement phase. In recent years, researchers are focused on such cloth. the mixture of Glass/ Carbon fiber offers a more attractive combination of the properties eg. Stiffness and toughness than composite supported the only fiber type [1]. Most of the researchers consider carbon fiber reinforced composites only, Mespoulet et.al presented that Carbon fiber bolstered composites are in an epoxy matrix composite that shows the relative distinction in peel strength (50 MPa) and plane lastingness (up to 1400 MPa) [2]. The Interlaminar property of the composite is an important factor for the performance of the composite. Delimitation is during all one amongst one in every of one among the foremost critical failure modes in a covered composite structure, delamination in the composite can happen if the strip stresses surpass the lastingness of the network. Therefore, it's essential to reinforce interlaminar fracture toughness to avoid delamination. The inter fracture toughness of laminated composites are mainly depended upon the subsequent important factors (Fig. 1).

i. Processing technique
ii. Stacking sequence
iii. Type of matrix
iv. Type of fibers etc.

D ratna [3] et al. reports that the modified epoxy mixture matrix phase improves the adhesion property of the composite. It can be achieved by blending with a versatile modification of the epoxy; which improves the good bonding strength of the epoxy resin. Kageyama et al investigate that the interlaminar composites fracture value in higher, the static, and fatigue interlaminar fracture characteristics were improved by the interlayer toughened carbon/epoxy [4]. The Mode I break the pace of development reported as a component that the very pinnacle of vitality boding rate (Fig. 2.).

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Fig. 1. Carbon, glass fabric and epoxy resin.

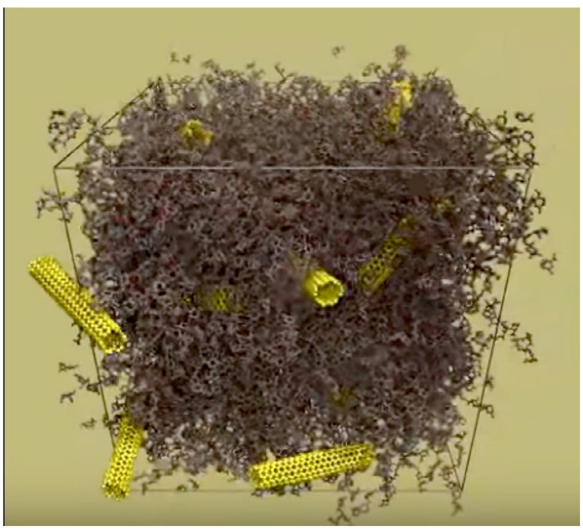

Fig. 2. Mixture of CNT with epoxy resin.

Ye Zhu [5] et al., investigates that the carbon nanofillers in the various functional surfaces; the un-functionalized carbon nanofibers, glycidyloxypropyl-time thoxysilane carbon nanotubes are expanding the interlaminar crack strength of an S2-glass fiber/epoxy composites. The microscopic analysis was supported bythe infinitesimal assessments of the break surfaces. The increased thickness of the high proportion of nanofillers are the cause of the easiest snare between the filler and glass filaments and adequately discourage to the interlaminar split the proliferation (Table 1).

Table 1
Properties of Materials.

Materials	Properties
Glass Fibers	GSM = 200
	Density = 1.77 g/cc
	Thickness = 0.30 mm
	Tensile strength = 1500 MPa
	Young's modulus = 38 MPa
Kevlar Fibers	GSM = 300
	Density = 1.44 g/cc
	Thickness = 0.30 mm
	Tensile strength = 1430 MPa
	Young's modulus = 100 MPa
Epoxy resin	Minimum curing: Time 15–30 mins at 1000C
	Shear strength: 1.4 Kg millimeter square min
	Viscosity : 9000–12000 mPa.s at 25 deg C
CNT	L_{Avg} = 1.5 µm
	D_{Avg} = 10 nm
	Surface area = 250–300 m^2/g

Huiming Ning [6] et al., reports that the strategy to upgrade the interlaminar mechanical properties of carbon fiber fortified plastic (CFRP) laminates. In the Mode-I crack durability and opposition, strength was improved with the merging of graphene oxide strength and epoxy interleaf into the interface of CFRP lamination.

Jingjing Jia [7] et al., utilized CVD developed of the 3D network arrange graphene; the interleaves to toughen and fortify optical fiber strengthened by the epoxy composite. The consolidation of the 3D arrangement of graphene in the mid-plane astounding was increased the interlaminar shear quality.

Masaki Hojo [8] et al., found that the interlaminar break sturdiness and delamination of the (CF)/epoxy. The split arrangement develops the conduct with the carbon fiber (CF)/epoxy covers to the similar epoxy interleaf. In the Mode II; delamination shows the weakness limit of the epoxy-interleaved and the overlaythickness of 2–2.3occasions over those of the base CFRP lamination. While the sturdiness of the interleaf is that the key factor of the under mode I, the thickness of the transaction is that the key factor under mode II.

L Lee [9] reports that the harm system decreases to the tractable properties of E-glass yarns during the weaving of three-dimensional textures for polymer-based composites. Saravanan et al., investigated the exploratory of the sewing type z-axis support to deal with the broad interlaminar sturdiness of laminated composites. The results outcomes demonstrated that the proposed technique for z-axis fortification was very compelling in controlling the de-overlay related to harm engendering [10–13]. From the summary of the literature review, it was concluded that the fracture toughness within the composite is often enhanced by the subsequent methods (i) Introducing strong resin matrix (ii) Introducing interplay of micro and nanolayer (iii) stitching, z-pinning or weaving techniques [14–16].

Most of the work reported in enhancing the fracture toughness of one fiber type composite only. This work made an effort to reinforce the toughness fracture of a Glass/Carbon hybrid composite by introducing the Nanofillers in the matrix phase. From the recent research, polymer blending is identified as an efficient thanks to fabricating composite with promising mechanical properties. The incorporation of nanofillers within the matrix through polymer blending improves the mechanical properties simply like the high explicit firmness, quality, and electrical properties [17–19]. CNTs (Carbon nanotubes) make them promising support for making multifunctional composites [20–21]. The high area of CNTs is liable for strong intrinsic van der Waals forces between the individual nanotubes and it causes the CNTs to agglomerate [22]. Therefore, it's essential to avoid agglomeration with uniform dispersion. It's noted that one among the most problems in using CNTs is as support of composites is scattering them consistently inside the grid because of high territory and enormous aspect ratios [23]. During this research, Mode I interlaminar fracture toughness of woven

Glass/carbon reinforced epoxy composites investigated. The handy lay-up technique is employed to fabricate hybrid composite [24]. The double cantilever beam (DCB) specimens were used to measure the interlaminar fracture toughness.

2. Materials and methods

All materials utilized in this work are commercially available. a clear weave Glass fabric with 200 GSM and a clear weave Carbon fabric with 450 GSM were used as reinforcement. Lapox L12 (3202) may be a liquid, unmodified epoxy of medium viscosity which may be utilized as a polymer matrix with K6 Hardener.

Hardener K6 is a low viscosity room temperature curing agent. It is commonly employed for the hand lay-up method. CNT are used as nanofillers. The properties of fiber, resin, and CNT are given in the table.

3. Sample preparation

The hybrid composite material under investigation is fabricated from six different configurations of six-layer of fibers with epoxy resin. Six layers of woven glass and Carbon fabric reinforced epoxy resin composite laminates were fabricated using hand lay-up method. Various lamina stacking sequences are shown in Table 2. The composite specimen is fabricated as a 250 mm × 250 mm plate. From the plate 180 mm, long 25 mm wide with initial crack length 20 mm specimens are cut by a saw. The specimens are designed according to ASTMD5528. The specimens are bonded with piano hinges. The DCM test was performed in an Instron EN6033 test machine. Load vs displacement of each specimen is recorded. However, mode 1 interlaminar fracture toughness is directly obtained from the computerized Instron machine (Table 3).

4. Result and discussion

Fig. 3 shows load vs displacement for 0% of CNT from this graph it is noted that specimen ID2 gives lower displacement similarly specimen ID 1 gives higher displacement for various loads. The specimen ID 2 is made of 100% carbon fibers and specimen ID1 is made of 100% glass fiber in the reinforcement phase of hybrid composite. The main reason for the behavior of this specimen is the presence of Carbon fibers in the reinforcement phase. Because the Carbon fibers are stiffer than the Glass fiber.

Fig. 4 and Fig. 5 illustrate the 1% and 2% CNT reinforcement. It is observed that the specimen ID 7 is the second lowest and specimen ID 6 is the second-highest displacement value among the group of specimens having 0% CNT. Because specimen ID 7 is made of 66.66% Carbon fibers and 33.33% Glass fibers and the specimen ID 6 is reversed in the fiber percentage.

Even though specimen ID 3, ID 4, and ID 5 having 50% percentage of Glass fiber and 50% percentage of Carbon fiber in

Table 2
Lamina stacking sequence.

Material Id	Composite stacking sequence	% of glass fiber	% Carbon fiber
1	G/E/G/E/G/E/G/E/G/E/G	100	–
2	C/E/C/E/C/E/C/E/C/E/C	–	100
3	G/E/C/E/G/E/C/E/G/E/C	50	50
4	G/E/G/E/G/E/C/E/C/E/C	50	50
5	G/E/C/E/C/E/G/E/C/E/G	50	50
6	G/E/G/E/C/E/C/E/G/E/G	66.67	33.33
7	C/E/C/E/G/E/G/E/C/E/C	33.37	66.66

Table 3
Specimen ID for samples.

Specimen Id	Composite stacking sequence	0% CNT
1	G/E/G/E/G/E/G/E/G/E/G	
2	C/E/C/E/C/E/C/E/C/E/C	
3	G/E/C/E/G/E/C/E/G/E/C	
4	G/E/G/E/G/E/C/E/C/E/C	
5	G/E/C/E/C/E/G/E/C/E/G	
6	G/E/G/E/C/E/C/E/G/E/G	
7	C/E/C/E/G/E/G/E/C/E/C	
Specimen Id	Composite stacking sequence	1% CNT
8	G/E/G/E/G/E/G/E/G/E/G	
9	C/E/C/E/C/E/C/E/C/E/C	
10	G/E/C/E/G/E/C/E/G/E/C	
11	G/E/G/E/G/E/C/E/C/E/C	
12	G/E/C/E/C/E/G/E/C/E/G	
13	G/E/G/E/C/E/C/E/G/E/G	
14	C/E/C/E/G/E/G/E/C/E/C	
Specimen Id	Composite stacking sequence	2% CNT
15	G/E/G/E/G/E/G/E/G/E/G	
16	C/E/C/E/C/E/C/E/C/E/C	
17	G/E/C/E/G/E/C/E/G/E/C	
18	G/E/G/E/G/E/C/E/C/E/C	
19	G/E/C/E/C/E/G/E/C/E/G	
20	G/E/G/E/C/E/C/E/G/E/G	
21	C/E/C/E/G/E/G/E/C/E/C	

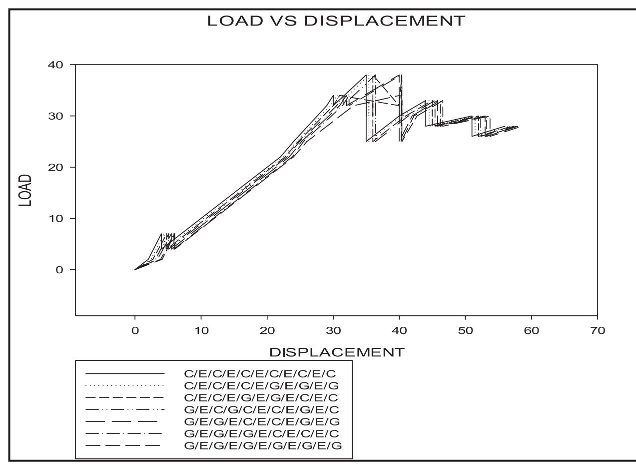

Fig. 3. Load vs displacement for 0% CNT.

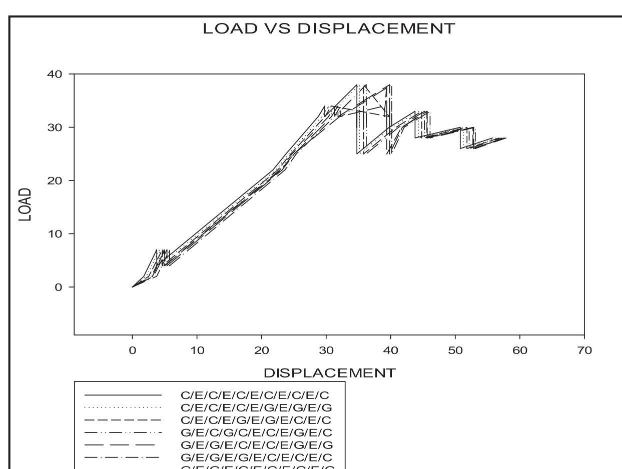

Fig. 4. Load vs displacement for 1% CNT.

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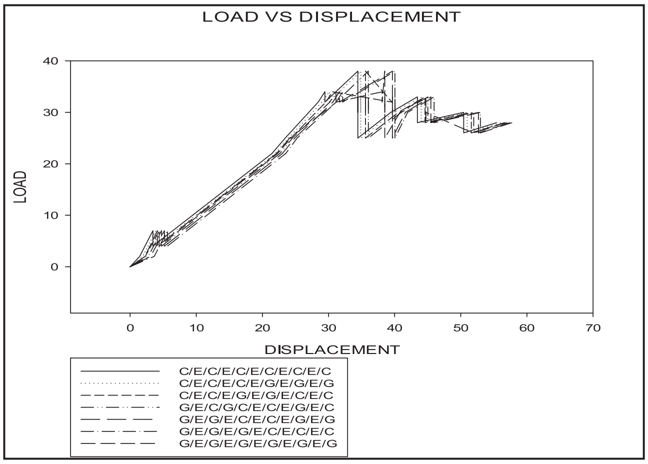

Fig. 5. Load vs displacement for 2% CNT.

the reinforcement phase, specimen ID 3 has the lowest displacement value among these three specimens. Because the fashion of ID 3 isan alternative lamina stacking sequence of glass and carbon fibers. It is found that the lamina stacking sequence is one of the factors for the response of the material under loading. Similarly, when compared to specimen ID 4 and ID 5, ID 5 has higher stiffness.

Fig. 4 and Fig. 5 show the load vs displacement for 1% CNT and 2% CNT respectively, the same trend of displacement curve like graph 3 is followed. But increase CNT in the matrix phase which increases the stiffness of the specimen.

Fig. 6 to work 8 shows the composite toughness vs different percentage of CNT (0 to 2%). it's found that composite toughness is increase when the percentage of CNT increases up to a quarter. the most reason is fiber bridging is happening in the specimen. The crack spread over the inner laminar layer of the fiber; which contains epoxy with the nanofibre the contact area of the carbon fabric and matrix increases the strength. Fig. 9 shows the composite toughness vs different percentage of CNT. it's found that composite toughness is increase when the percentage of CNT increases by upto 1% (Fig. 7).

The mid-plane of the CNT mixed which resin-rich layer deforms elastically and plastically; which consumed more energy during the deformation and crack spread over from the crack tip because fiber bridging has occurred in the specimen. It's also noted that increasing CNT beyond 1 wt% of CNTs. are often attributed to the slippage among CNT's. It results in reducing the fracture toughness of the hybrid composite (Fig. 8.).

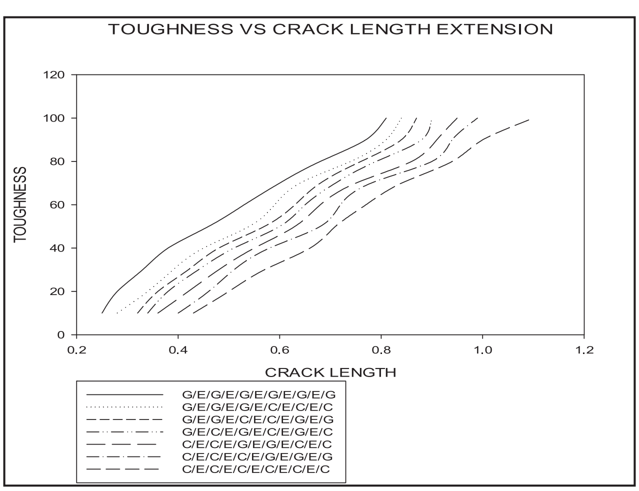

Fig. 6. Toughness vs crack length extensions for 0% CNT.

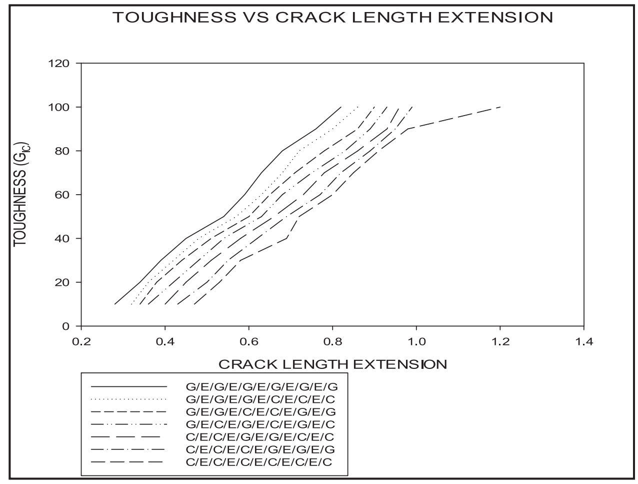

Fig. 7. Toughness vs crack length extension for 1% CNT.

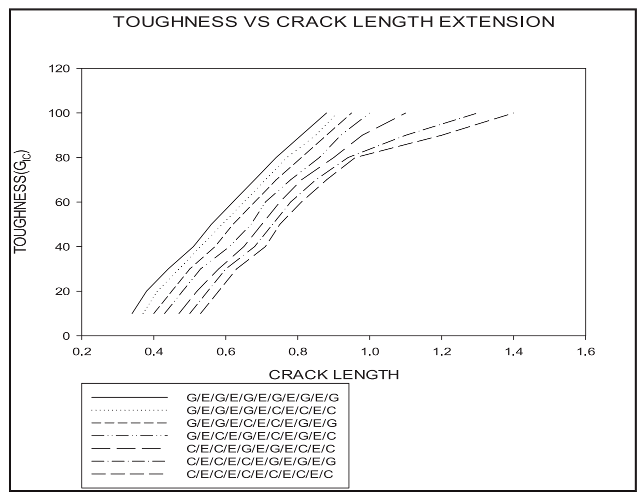

Fig. 8. Toughness vs crack length extension for 2% CNT.

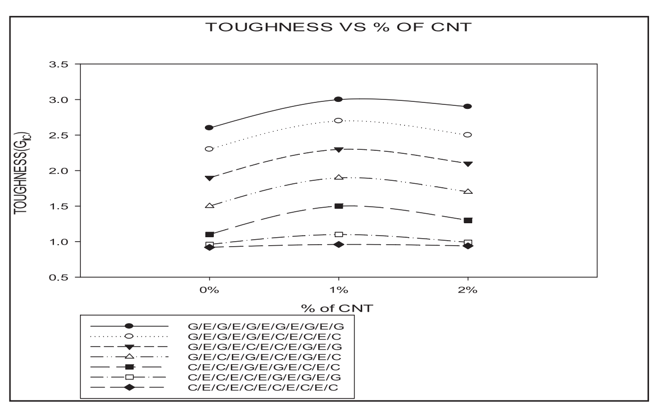

Fig. 9. Toughness vS % of CNT.

5. Conclusion

The carbon and glass-basedhybrid composites prepared in six different fashion and presented. TheCNT reinforcement on the epoxy matrix phase varied in three levels notably 0%, 1%, and 2%. The results of the mode 1 investigations presented. The increase inthe percentage of carbon fiberimproves the stiffness of the composite. The recommended increase of CNT reinforcement limited to 1%(weight percentage). The properties of hybrid composites with various fashions were varying between carbons composite to glass composite in the respective CNT reinforcement case.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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