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Mechanical Characterization of Hybrid Polymer Composite for Marine Application

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Abstract

An investigative work was conducted to examine the tensile, flexural and impact strength of carbon fiber reinforced vinyl ester composites filled with different proportions (0, 0.5, 1, 1.5 and 2) of graphitic carbon nitride (g-C_3N_4) and silicon nitride (Si_3N_4) filler. Composites were fabricated by hand layup method. Results showed an increase in tensile strength of g-C_3N_4 and Si_3N_4 particles content by 1% and beyond which the strength decreased. With the addition of 1wt% of g-C_3N_4 and Si_3N_4 in carbon fiber reinforced vinyl ester composites, the flexural strength increased to 16% and the tensile strength increased by 10%. The eroded surface of specimen was observed under scanning electron microscope and the results are reported. Incorporation of nano fillers in hybrid polymer composite will enhance the mechanical properties. Hence hybrid C-V extensively used in marine applications.

1. Introduction

In recent times, hybrid polymer composite materials application has been considerably increased in various fields like aerospace, medical, electrical, marine and automotive industry due to high strength, low density and low cost. Advanced hybrid polymer composite materials play a central role in current and future innovation programs. Hybrid composites exhibit superior mechanical and tribological properties than FRP. Nano fillers materials are added to the composite material to enhance mechanical and tribological properties. Arumuga Prabu et al.[1] studied the fiber orientation and filler content effectively on the performance of FRP composites. Wang et al.[2] studied the effect of fiber orientation on mechanical properties on unidirectional glass fiber reinforced epoxy composites. Experimental results showed that improved mechanical properties of these composite have great dependence on fiber orientation. M.S.EL-Wazery [3] has been reported that the mechanical properties of glass fiber reinforced with polyester composites and observed that due to the interfacial bonding strength between the matrix and reinforcement, the tensile strength of the composite increased. Suresha B. et al.[4] investigated the influence of micro SiC/graphite particles on the mechanical characteristics of carbon fiber reinforced with vinyl ester hybrid composites and reported that tensile strength, flexural and modulus increased with increasing micro filler ratio. It is concluded that for 6 wt% graphite filled carbon fiber-vinyl ester composite showed superior strength and modulus compared to SiC filled CV composites. Muralidhara et al.[5]

researched on the mechanical properties of carbon fiber/epoxy composites under three dissimilar fiber architecture (T800CF/Ep,T700CF/Ep, T300CF/Ep) thereby concluding that tensile and flexural properties are improved in T800CF/Ep composite when compared to other composition. Fouda et al. [6] studied the mechanical properties of carbon fiber reinforced with epoxy composites because the more adhesion bond of the resin matrix. Carbon fiber reinforced polymer composites are superior compared to the metals and other polymers when used during spring applications [7]. P.Pratap Naidu et al.[8] have reported that the outcome of g-C_3N_4 on mechanical behaviour multidirectional hybrid glass-epoxy composites. Filler percentage was altered between 0.1, 1.5, 2, and 2.5 wt% and concluded increased, the tensile strength and flexural strength are increased by 11% and 13% occurring at 2 wt% of nano graphitic carbon nitride filler. Dipen Kumar Rajak et al. [9] conducted a study on overview of composite materials, their characterization, classification, advantages, physical and mechanical properties. The new advanced manufacturing technology was used fabricating the composites laminates when compared to conventional methods and reported that percentage of reinforcement, resin to hardener ratio, and micro/nano fillers to improve the mechanical, and tribological properties. Sumit pawar et al.[10] investigated the mechanical properties of silicon nitride particles filled with epoxy composites. It was found that compressive strength, hardness and tensile strength are increased up to 50 wt% and 20 wt% of silicon nitride content. To determine the strength parameters of carbon fibers reinforced composite material to achieve the desired mechanical properties, several studies have been carried out [11].

Against this background, in present work, a class of composite is fabricated in which the continuous phase is thermoset vinyl ester matrix; discontinuous phase is carbon fiber and a nano size graphitic carbon nitride and silicon nitride particles. Simple hand lay-up method is used for fabrication of composites with wide range of filler content. The various testing involve physical testing in which microstructure study of composites was performed together with evaluation of density and void content. Under mechanical testing, tensile strength, flexural strength and impact were evaluated.

2. Experimental

2.1 Materials

The viscosity of vinyl ester 400 cP is the resin as used in the present study. Methyl ethyl ketone peroxide is curing catalyst and cobalt naphthenate as accelerator are used. All these materials were procured from Sathyam Fibertex, Coimbatore. 200 GSM woven carbon fabric with mass density 1800 kg/m^3, tensile strength of 4000 MPa, tensile modulus of 240 GPa purchase from RPI, Bangalore, and primary reinforcement is carbon fiber utilized in composites. Graphitic Carbon Nitride (g-C_3N_4) and Silicon Nitride (Si_3N_4) have spherical shape, average particle size 50-200 nm used as secondary reinforcement. Both graphitic Carbon Nitride (g-C_3N_4) and Silicon Nitride (Si_3N_4) were supplied by Nano Wings Private Limited, Telangana, India.

2.2 Fabrication of composites

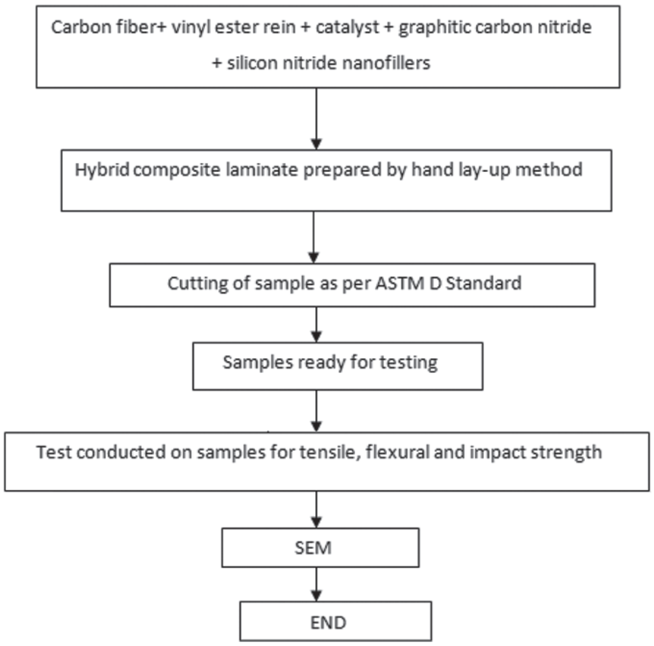
Hand lay-up method is used to fabricate the composites. Initially mold release sheet is applied to the granite. Vinyl ester resin and catalyst are mixed by the weight ratio of 10:1. Then, nanofillers are added in this mixture. Carbon fibers are placed in mold, one above the other, and vinyl ester resin mixture is applied to the mat in the mould measuring 300x300x5 mm^3. Then a eliminate air bubbles by using brush, or roller. The desired thickness is obtained by following the above procedure. All the laminates have been cured post cured at 80^{o}C for 1h. Table 1 shows compositional

Table 1: Composite selected for the present work

Designation	Matrix Vinyl Ester resin (wt.%)	Reinforcement Carbon Fiber (wt.%)	Nano fillerg C_3N_4(wt %)	Nanofiller Si_3N_4(wt%)
C-V	40	60	-	-
0.5 C-V	39	60	0.5	0.5
1 C-V	38	60	1	1
1.5 C-V	37	60	1.5	1.5
2 C-V	36	60	2	2

details of hybrid laminates. The composite laminates are machined using WJAM to get coupons for conduction of tensile, flexural and impact testing. Table 2 shows the flow chart of hybrid polymer composite.

Table 2: Shows the flow chart of hybrid polymer composite



2.3 Tensile Test

The tensile test is conducted as per the ASTM D3039 standard using by UTM of a utmost loading capacity is 100 kN. UTM Instron-3369 used for the appraisal. The gauge length, gauge width, and thickness of the specimen are 150 mm x 20 mm x 5 mm. This test is performed at 240C and constant crosshead speed of 10 mm/min was fixed throughout the test. Five specimens of each type tested, and mean results are obtained. Tensile test specimen is shown in Figure 1. The ultimate tensile strength is calculated using the equation (1).

Tensile strength = P max/bh MPa ... (1)

Where, P = Maximum load in N.

b = width in mm.

h = thickness in mm.

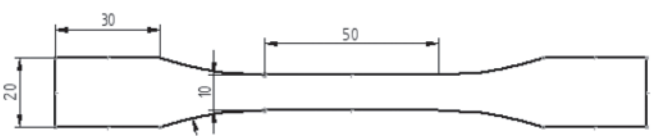


Figure 1: Tensile test specimen

2.4 Flexural Test

Flexural test were conducted as per the ASTM D790 standard at room temperature. The specimen size is 130 mm x 14 mm x 5 mm. The machine is run under 5 mm/min of crosshead speed. Deflection reading and flexural strength results from the testing is recorded. Figure 2 shows flexural test specimen. The ultimate flexural strength is calculated using the equation (2).

Flexural strength = 3FL/2bh2 MPa ... (2)

Where F = Maximum load in N,

L= span length in mm,

b = width in mm and

h = thickness in mm

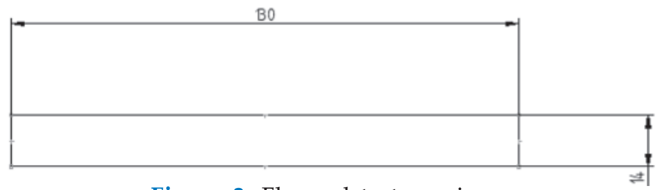


Figure 2: Flexural test specimen

2.5 Impact test

The izod tests were conducted as per the ASTM D256 using by impact testing machine. The sample size of 80 mm x 14 mm x 5 mm was considered for evaluation. Preparation of 450 V-notch on the centre of the specimen. The specimens were kept in machine. Pendulum is raised to specific height and then released. Pendulum down hitting notched specimen and breaking the specimen. Five specimens of each type were tested, and their mean values were reported. Izod impact test specimen has been shown in Fig.3.

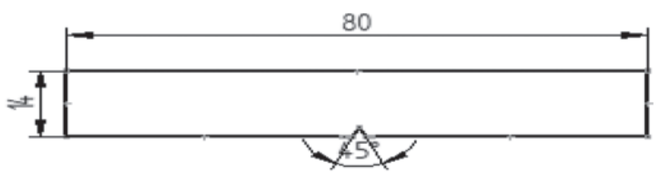


Figure 3: Izod impact test specimen

3.0 Results and Discussion

3.1 Tensile Strength

Mechanical properties of hybrid polymer composite materials are listed in Table 3. The experimental results of tensile strength are illustrated in Fig.4. Composite with 0% fillers in carbon/vinyl ester has strength of 515 Mpa. The g-C_3N_4 and Si_3N_4 filled composites showed maximum tensile strength of 1C-V compared to 0.5, 1.5, 2 and unfilled C-V composite. The results show that highest tensile strength is 563 MPa followed by 20 layers of C-V content with 515 MPa and strength has increased by 10% [12]. Tensile strength is decreased by the more addition of filler content (at 1.5 wt%).

Table 3: Mechanical properties of hybrid composite materials

Composite Designation	Tensile Strength (MPa)	Flexural Strength (MPa)	Strength Impact (KJ/m2)
C-V	515	263	110
0.5 C-V	539	284	112
1 C-V	563	305	114
1.5 C-V	528	289	105
2 C-V	494	273	97

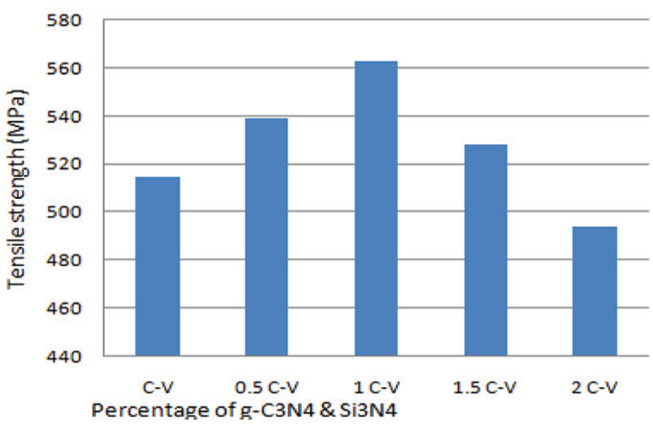


Figure 4: Tensile strength as a function of g- C_3N_4+Si_3N_4 filler content

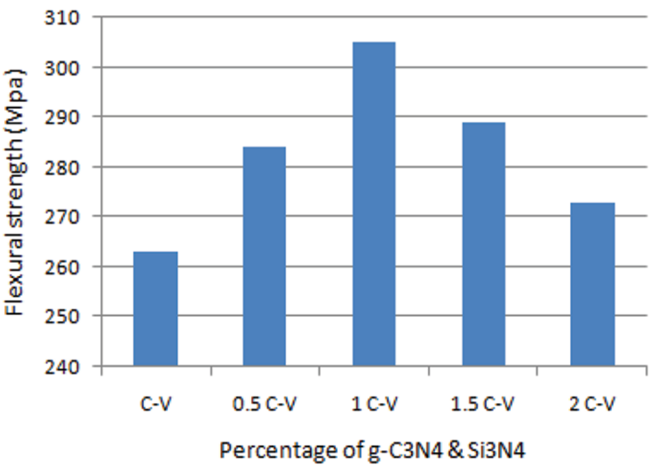


Figure 5: Flexural strength as a function of g- C_3N_4+Si_3N_4 filler content

3.2 Flexural Strength

The experimental results of flexural strength is shown in Fig.5. Flexural strength of 1 C-V nano composites exhibits higher flexural strength of 305 MPa as compared to 0.5, 1.5, 2 and unfilled C-V composites. The composite with 1wt% of g-C_3N_4 and Si_3N_4 in 20-layers of carbon fiber showed 16% strength increased and 2wt% g-C_3N_4 and Si_3N_4 composite showed 3.8% respectively [12]. The flexural strength is reduced when furthermore addition of fillers.

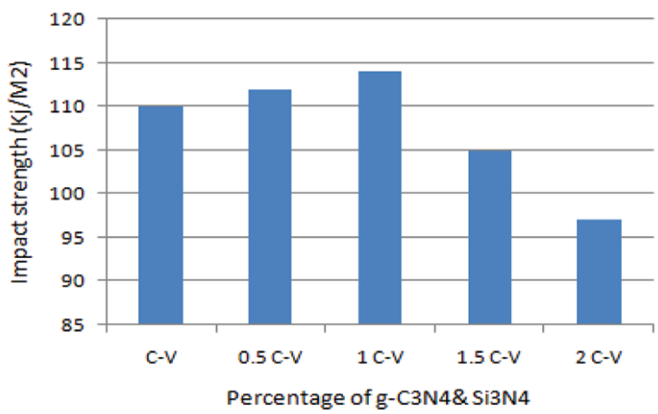


Figure 6: Impact strength comparison for different composition of the composites

3.3 Impact strength

Impact strength increases with increase in the filler loading. Fig.6 shows that amongst all, 1C-V nano composites exhibits higher impact strength of 114 KJ/m^2 as compared to 0.5, 1.5, 2 and unfilled C-V composite. Thus g-C_3N_4 & Si_3N_4 based C-V nano composites have a capability to absorb more energy and has greater fracture strength as compared to other composites.

3.4 SEM

Five composites were investigated for the failure mechanism. The tensile fractured surface and impact fractured surface of specimens were analyzed using SEM as shown in Figs. 7 and 8. The tensile fractured surface SEM image of 1C-V composites showed that few fibers are pull out and matrix-fibre interface leading to failure in tensile strength. 1C-V composites had less micro-voids than other composites, hence their values were better. During the study conducted on carbon fiber/epoxy composites with improved mechanical properties, the main factor is fiber pull-out which is result of weak interfacial adhesion [5]. Fig.8 represents the image of impact fractured surface of 1C-

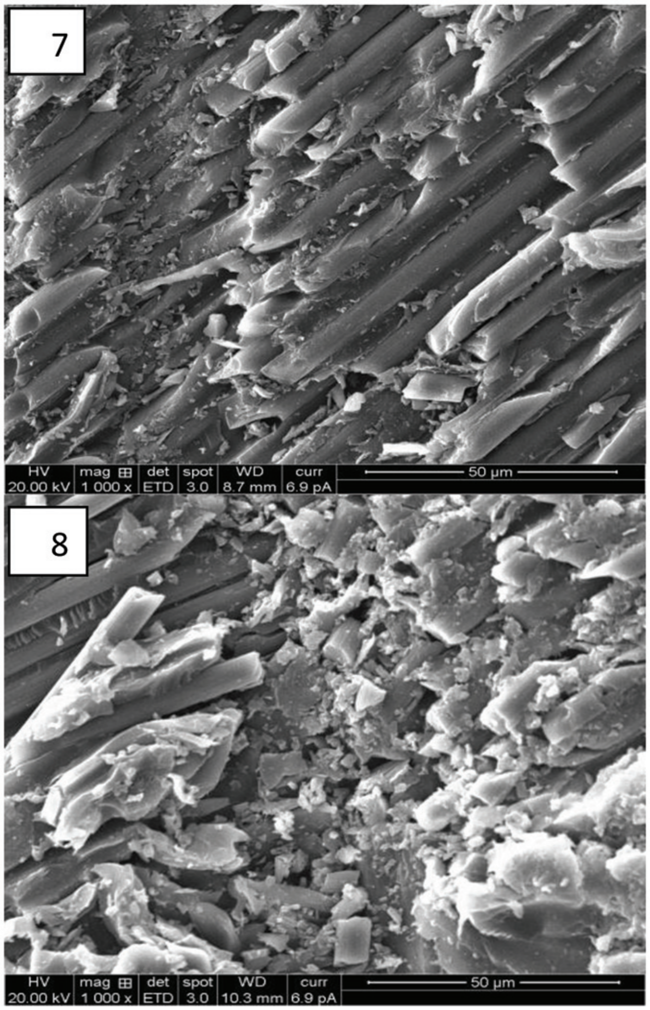


Figure 7&8: Photomicrographs of tensile fractured surface of 1C-V composites and impact fractured surface of 1C-V composites

V composite respectively and few fibers pull-out and micro-voids were observed. The impact strength is increased from 0 to 1 wt% by the addition of nano fillers and further more addition of nanofillers, the strength is decreased. Compared to unfilled C-V composites, the superior ductile nature of the composites helped in absorbing more impact energy. The increase in impact strength proves that the adhesion between matrix and fiber is significant. It shows that higher ratio of filler inclusion may result in poor matrix reinforcement bonding, poor load carrying capacity and delamination. Comparatively, 1C-V composites had a smaller amount of micro- voids than 0.5, 1.5, 2 and unfilled C-V composites which give rise to improved mechanical properties.

4.0 Conclusions

Based on the research work, the following conclusions can be made from the present work:

- The results obtained from the tensile test, tensile strength for 1wt% g-C_3N_4 and Si_3N_4 filled C-V composite is more compared to 0.5, 1.5 2 wt% g-C_3N_4 and Si_3N_4 C-V and unfilled composite. Tensile strength is decreased at 2 wt% due to the presence of higher filler content.
- The results obtained from the flexural test, flexural strength for 1wt% g-C_3N_4 and Si_3N_4 filled C-V composite is more compared to others and its maximum value is 305 MPa. The addition of more than 1wt% g-C_3N_4/Si_3N_4 filler showed a reduction in flexural strength of the composites.
- The impact strength increased by up to 1wt% filler addition. Impact strength significantly reduces at 1.5wt% C-V composite due to improper distribution of fillers.

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