RESEARCH PAPER | Engineering | Volume : 3 | Issue : 2 | February 2013 | ISSN - 2249-555X

Design, Fabrication and Characterization of Nano Tubes Reinforced Epoxy - Carbon Fiber Composites

KEYWORDS: Epoxy resin, Carbon fiber, impact strength, tensile strength

J. Jayaseelan
Assistant Professor, Advanced Research Institute Dr. M. G. R. Educational and Research Institute University Adayalampattu, Chennai- 600095, Tamil Nadu, India

P. Palanisamy
Dean, Advanced Research Institute Dr. M. G. R. Educational and Research Institute University Adayalampattu, Chennai- 600095, Tamil Nadu, India

K. R. Vijayakumar
Professor, Advanced Research Institute Dr. M. G. R. Educational and Research Institute University Adayalampattu, Chennai- 600095, Tamil Nadu, India

ABSTRACT *The goal of the present study is to investigate the influence of carbon nano tubes on the mechanical behavior of carbon fibre reinforced polymer laminates. Hence tailoring of composite material is done by addition of another inherently tough material (Nano-tubes) by 0%, 1.5%, 3% and 4.5% to conventional epoxy resin system. The fillers are added to the epoxy matrix of the laminates. These composite materials are tested for its tensile strength, impact strength, bending strength and heat deflection and the results are plotted. Morphology of composite materials is also analyzed. The effects of these fillers on the mechanical behaviour are intensively investigated. A small change in chemical treatment of the nano tubes has a great effect in the mechanical and morphological properties of nano composites due to effective load transfer mechanism and state of dispersion. The changes in properties are compared with basic material.*

1.0 INTRODUCTION

A composite material is a non-homogenous material having two or more components including reinforcing elements that provide the necessary mechanical characteristics of the material and a matrix that allows uniform deformation of the reinforcements[2,10].Various configurations of the composites such as beams, columns, rings, panels and plates, circular cylindrical shells are used in a large number of engineering components.

Composites are becoming increasingly used in structural applications because of their high specific strengths (failure stress per unit width) and specific stiffness (stiffness per unit weight) [7, 8]. Advanced structures with integrated self-monitoring and control capabilities are increasingly becoming important due to the rapid development of smart space structure mechanical systems. Smart structure technology featuring a network of sensors and actuators, real time control capabilities, computational capabilities and host materials will have tremendous impact upon the design [5]. Fiber-reinforced polymeric composites have been analyzed extensively and considered as advanced materials for many applications [4]. In the present work Fiber –reinforced composite made up of plain woven carbon fibers and Interpenetrating epoxy polymer matrices is considered. This composite material is a new polymeric composite material. The fracture modes of polymeric composites should be investigated so that the material can be applied to the real product.

There are several fracture modes in fiber reinforced: fiber breakage, matrix cracking, fiber/matrix debonding, fiber pull out, plugging and interlaminar delamination etc. Generally delamination is one of the main fracture modes in many advanced laminated composites structure [1]. Therefore, better understanding of the interlaminar fracture resistance of laminates is very useful for structural design and development of materials.

2.0 EXPERIMENTAL

2.1 Materials

Epoxy resin, Hardener (amine), Carbon fiber, Nano tubes as shown in Table 1. All chemicals were used as purchased.

2.2 Fabrication of composite laminates

The composite materials were prepared by hand lay-up technique. The carbon fiber used in this process was unidirectional (Areal Density: 175gm/m2). The carbon fiber was applied in three layers for each composite material. The epoxy resin was applied in between these layers and rolled well to reach the pores of the carbon fiber thus to form a better bond between them. The numbers of plates prepared were four in which one was basic with only epoxy resin and the other three was carbon nano tube in powder form mixed with epoxy in different ratios (1.5%, 3% & 4.5%).

S.No	Name	Epoxy (g)	Hardener (g)	CNT (g)
1	EP	300	150	---
2	1.5EPCNT	300	150	4.5
3	3.0EPCNT	300	150	9
4	4.5EPCNT	300	150	13.5

Table 1: Material Composition

3.0 CHARACTERIZATION

3.1. Tensile properties

The test specimen was positioned vertically in the grips of the testing machine. The testing speed of the crosshead was 0.5 mm/min. As the specimen elongates the resistance of the specimen increases and was detected by a load cell. An IBM computer connected with testing machine was utilized. The Trapezium testing software was used to record the test data. The elongation of the specimen was continued until rupture of the specimen was observed. Load value at break was recorded as shown in Table 2. The tensile strength at break (ultimate tensile strength) was calculated and shown in Figure 1.

S. No	Name	Maximum Load (N)	Tensile Strength (MPa)	Break Strain (%)	Tensile Modulus (MPa)
1	EP	15324	510.8	1.50	34055
2	1.5EPCNT	15790	526.3	1.3	40484
3	3.0EPCNT	16470	549	1.25	43920
4	4.5EPCNT	16284	542.8	1.48	36675

Table 2: Tensile Test Results

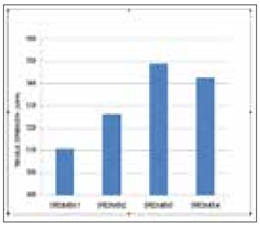

Figure 1: Comparison of Tensile strength of composite specimens

Volume : 3 | Issue : 2 | February 2013 | ISSN - 2249-555X

3.2 SEM Observation
After tensile tests, the fractured specimens were photographed in details and analyzed by Scanning Electron Microscopy (SEM). It was observed that the composite matrices without nanofiller exhibit a poor recovering property of the fibers, showing consequently a weak interfacial adhesion (Figure 2). When nanofiller (CNT) is added, the fibers show more homogeneous recovering by the matrix (Figure 3), resulting in a higher interfacial adhesion. In Figure 3 elastomeric phases are observed in the interfacial region of fibers-matrix, which contribute for higher plastic deformation of this thermoplastic matrix when compared to the non-nanofiller ones.

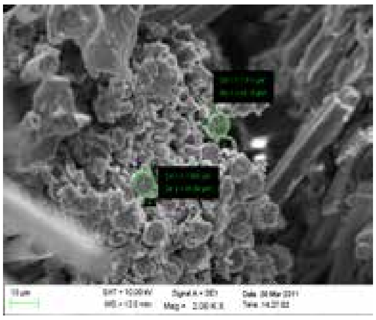

Figure 2: SEM of fractured specimens of the CF-EPOXY laminates after tensile tests

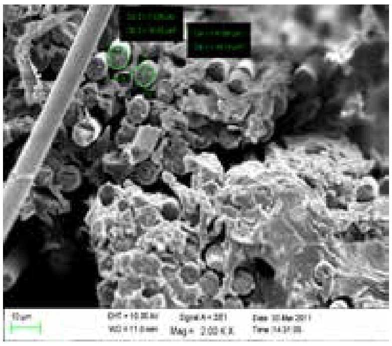

Figure 3: SEM of fractured specimens of CF-EPOXY/CNT after tensile tests

3.3 Impact Test
Izod impact test is carried out for the specimens shown in Figure 4. Energy absorbed was recorded and impact toughness was calculated and the results were shown in Table 3.

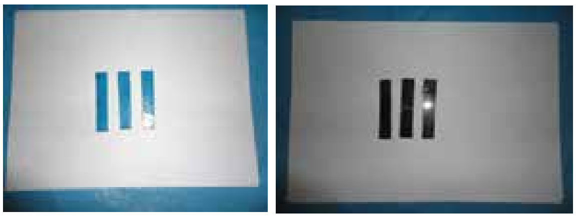

Figure 4: Specimen for Izod test

Impact is a very important phenomenon in governing the life of a structure. Izod impact is defined as the kinetic energy needed to initiate fracture and continue the fracture until the specimen is broken.

MATERIAL	ENERGY ABSORBED (Joules)	IMPACT TOUGHNESS (J/mm²)
(0% CNT)	34	79.77* 10^{-2}
(1.5% CNT)	38	94.27*10^{-2}
(3% CNT)	40	95.81*10^{-2}
(4.5% CNT)	34	81.47*10^{-2}

Table 3: Impact Test Results

3.4 Heat Deflection Test
Heat deflection test is carried out as per ASTMD648 standard as shown in Figure 5. After reaching the desired temperatures (280C, 500C and 750C), different loads 5 N, 10 N, 15 N and 20 N & 25 N was applied on the specimen and the deflection was noticed. The above tests (Table 4, 5) results show that specimen with Epoxy – CNT combinations possess less deflection when compared to specimen made of neat Epoxy.

Figure 5: Experimental set up for Heat Deflection Test

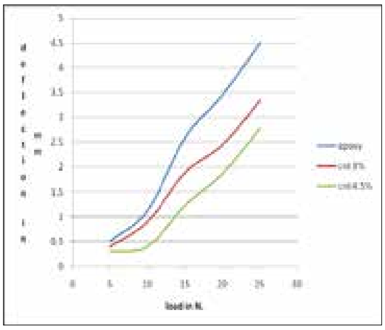

Table 4: Deflection result at 50°C

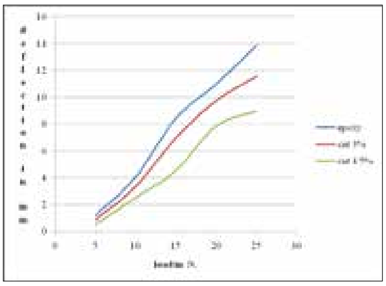

Table 5: Deflection result at 75°C

4.0 CONCLUSION
In this paper, the properties of carbon fiber / Epoxy reinforced with Multi walled carbon nano tubes were studied and comparison made with neat epoxy material.

It is observed that the tensile properties and impact strength seem to increase upto 3% CNT addition. Beyond which those properties tends to decrease.

The heat deflection test also confirms better results with addition of CNT material to regular carbon fiber-epoxy system.

The Scanning Electron Microscope results shows that CNT provide a better adhesive bond between the epoxy and carbon fiber and supports the above statements.

Thus with these enhanced features, the carbon fiber – epoxy/ CNT material can be used for aerospace, satellites and marine applications due to high strength to weight ratio.

Volume : 3 | Issue : 2 | February 2013 | ISSN - 2249-555X

REFERENCE 1. Rahoria, H., Jalili, N.: Composite Science And Technology; 65:2079-93, (2005). | 2. Meng, F., Zheng, S., Liu, T.: Epoxy resin containing poly(ethylene oxide)-block-poly(e-caprolactone) diblock copolymer: effect of curing agents on nanostructures. Polymer;47(21):7590–600 (2006). | 3. Francis, B., Thomas, S., Jose, J., Ramaswamy, R., Rao, VL.: Hydroxyl terminated poly(ether ether ketone) with pendent methyl group toughened epoxy resin: miscibility, morphology and mechanical properties. Polymer; 46(26):12372–85 (2005). | 4. Pickering, S.J.: Recycling technologies for thermoset composite materials – current status. Composite A; 37(8):1206–15 (2006). | 5. Boyard, N., Serre, C., Vayer, M.: A physical approach to define a class A surface in polymer thermosetting composite materials. J Appl Polym Sci; 103(1):451–61 (2007). | 6. May, C.A., Tanaka, G.Y.: Epoxy resin chemistry and technology, New York: Marcel Dekker; (1973). | 7. Vijaya Kumar, K.R. and Sundareswaran, V. "Dynamic Mechanical Properties of Epoxy Cyanate Matrix Composite under Varied Temperatures by Free Vibration Method", Journal of Vibration and Control, Vol. 17, No. 12, pp. 1905-1911, 2011. | 8. Potter, W.G.: Epoxide resins. New York: Springer; (1970). | 9. Mc Adams, L.V., Gannon, J.A.: Encyclopedia of polymer science and engineering, vol. 6. New York: Wiley–Interscience; 322–48 (1986). | 10. Jayakumari, L.S., Thulasiraman, V., Saroja devi, M.: Synthesis and characterization of cyanate epoxy composites, High Performance Polymers, Vol.19, 33–47 (2007).