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EVALUATION ON THE MECHANICAL PROPERTIES OF CARBON NANOFIBER REINFORCED EPOXY COMPOSITES USING ANSYS

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More than ever before nano particles such as carbon nanofiber (CNF) composites are being utilized in the wide applications like aircraft, marine, automotive etc. The optimization of this material for various loading and geometric configuration has become a primary concern to designers as well as manufacturers. Multiscale composites can be formed with better properties by combining nano particles with traditional reinforcement materials. This research focus on the development of such composites, through the use of carbon nanofibers (CNFs) reinforced in different weight ratios into the matrix. Each wt % of CNF was dispersed in the polymer matrix using two dispersion methods for homogenous mixing with matrix. Flexural behavior of composites has been analyzed to investigate the effect of epoxy matrix by adding CNFs in them. Better strengths are obtained at 0.5 wt% of Carbon nanofibers (CNF) in the polymer matrix. The flexural strength is interpreted with ultra-sonic testing and ANSYS simulation software to compare the actual strength of the coupons with anticipated one.

Keyword:
Polymer matrix-composite, Carbon nanofiber, Mechanical properties, ANSYS , Ultra - sonicator, ultra-sonic testing and Magnetic stirring.

1. Introduction

Recently many researcher focused on nano particles due to the significant mechanical properties of them. The reinforced nano particle composite is one of the discovering research areas in the material science and engineering. Aramid, glass, Kevlar and carbon reinforcement materials combined with Carbon nanofibers and other nano particles have drastic strength improvement [1].The diameter of Carbon nanofiber extent of variation between 100 nm-250 nm and the length of the CNF extent of the microns perspective ratio of diameter, length greater than 100 nm. It has good mechanical and physical properties. Composites have good properties enhancement due to the inclusion of nano fillers [2]. Epoxy resins are having many applications due to their high chemical and good mechanical properties. CNF 0.07 volume percentage is added with epoxy resin and then CNF and epoxy resin is sonicate by using ultra- sonication for uniform distribution. It increases the Young's modules to 98% [3].Homogenous dispersion of the CNF and resin enhances the modules and strength of CNF composites [4]. CNF inclusion improves the tensile and flexural strength up to 11% and 22.3% respectively compared with the composite without carbon nanofiber [5]. The coupons are fabricated in three combination of CNF 0.5%, 1 and 1.5% in Phenolic resin it improves the flexural strength and breaking strength 11.5% and 9%, respectively[6]. Carbon nanofiber plays several applications in aerospace such as mechanical properties, electrical conductivity and thermal transfer [7]. Applications of the CNF composites in aerospace vehicles are very tremendous and also in the defence research due to the good mechanical and high temperature resistance property [8]. In this research work we focus on the CNF reinforced with epoxy resin matrix in various weight ratios to optimize the flexural strength and it is interpreted with ultra-sonic testing and Ansys simulation software to justify the mechanical behavior of the composites investigated.

2. Fabrication Of Composite Coupons

Araldite standard epoxy resin (CY 230-1, HUNTSMAN) and hardener (Aradur HY 951) were purchased (Leo Enterprises Ltd) and directly used. Carbon nanofibers (CNF) (Sigma Aldrich) used in this study were of 100 nm in diameter, 20-200 µm long and of >98% carbon basis. The carbon nanofiber of 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1 gram by weight ratios of resin was dispersed in the resin matrix through two different methods. Stirring CNF with resin for 2 hrs with constant temperature 60˚ for mixing the CNF with the matrix. Stirring CNF with resin at 20 KHz for 2hrs in the ultra-sonicator for the homogeneous mixing of CNF and resin. One set of coupons fabricated with pure epoxy resin. Before fabrication, the solution was degassed in a oven for overnight. Finally the solution was added with the hardener and mixed homogenously with the resin and then it is poured into the different mould to get flexural testing coupons. The hand lay-up method is the simplest method for composite fabrication of coupons. Totally fifty five coupons are fabricated five coupons for each weight percentage .The thickness of the plate is 2.5 mm, width 25 mm and length is 80 mm were fabricated and cut with the help of diamond cutter without any edge damage. The ASTM D 790 standard coupons are shown in figure 1 a & b.

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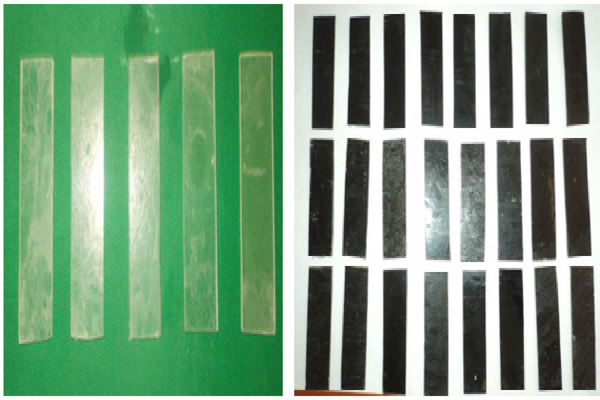

(a) (b)

Figure 1. (a) Epoxy pure resin coupons (b) Carbon nanofiber reinforced Flexural coupons.

2.1 Flexural Testing

Three point Flexural testing was conducted using a 10-ton universal testing machine (UTM). The support spans length was 60 mm apart and the rate of cross head motion was 0.5 mm/min. Figure 2 shows the test setup at which experiments were conducted. The load was gradually applied by the UTM upto the failure of the coupons. This test was repeated for all the coupons.

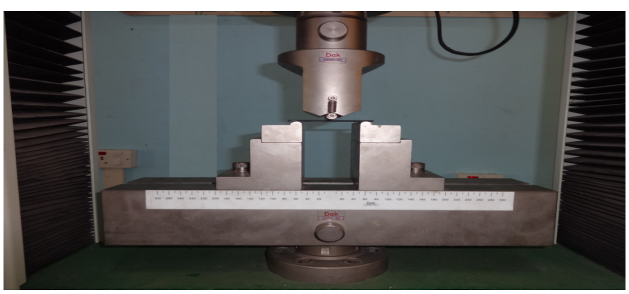

Figure 2. Flexural test setup.

2.2 Pulse-echo ultrasonic testing:

Ultrasonic testing (UT) was carried out according to USM 35 specifications. UT is a versatile inspection method to identify the internal and external flaws in the material. In the setup, a transducer sends out a pulse of energy and receives the energy back. Reflection occurs due to the presence of discontinuities and the surface of the test sample. The amount of reflected sound energy is displayed with the change of time, which provides the inspected information about the size and the location of the flaws as shown in figure 3.

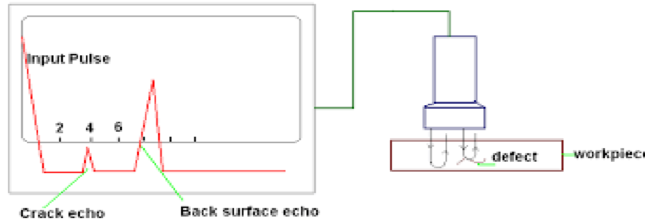

Figure 3. Working principle of an ultrasonic testing

Ultrasonic testing (UT) was conducted on the coupons to identify the defects. Out of fifty five coupons tested total of fourty six coupons were defect free (4 in Pure resin and 42 in CNF reinforced coupons). The cavities and crack were identified on the surface of the pure resin and the CNF reinforced coupons as shown in table 1. Out of all coupons fabricated, 5 coupon with a crack defect and others were found to have only cavities. The most important fabrication defect that is likely to occur in practice is cavity (the presence of voids). Some of the other defects occur very rare. Cavity can occur because of the air trapped between the surface and the layer during the fabrication of coupons by hand lay-up method. It could also be caused by unstable entrapment of air moieties during the curing of matrix (resin). The ultrasonic testing measures the variation in wave amplitude when passing through the coupons. The amplitude shows the defect size and the area of the defect present. The other defect, crack is not generally expected to be found. Crack will generally lead to failure growth before a critical stage is reached. Cracks generally reduce the flexural strength which is clearly understood from the flexural examination of coupons.

Table-1 Ultrasonic scanning result

Resin Defect observed	CNF 0.1% Defect observed	CNF 0.2% Defect observed	CNF 0.3% Defect observed	CNF 0.4% Defect observed	CNF 0.5% Defect observed	CNF 0.6% Defect observed	CNF 0.7% Defect observed	CNF 0.8% Defect observed	CNF 0.9% Defect observed	CNF 1% Defect observed
Defect free	Defect free	Defect free	Defect free	Defect free	Defect free	2mm crack	Defect free	Defect free	1 mm cavity	Defect free
2mm cavity	Defect free	Defect free	Defect free	2mm crack	Defect free	Defect free	Defect free	Defect free	Defect free	3mm crack
Defect free	Defect free	Defect free	Defect free	3mm cavity	Defect free	Defect free	Defect free	Defect free	Defect free	Defect free
Defect free	Defect free	Defect free	Defect free	Defect free	Defect free	Defect free	Defect free	Defect free	Defect free	2mm crack
Defect free	1mm crack	Defect free	Defect free	Defect free	Defect free	Defect free	1mm cavity	Defect free	Defect free	Defect free

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2.3 Finite Element Analysis

ANSYS is general purpose finite element analysis software package. This type of analysis is typically used for design and optimization of systems which are too complex to analyze by hand. This method allows to model composites materials with specialized elements called layered elements. ANSYS simulation involves mainly three steps, preprocessing, solving and post processing. Preprocessing involves creation of geometrical model, nodes, elements, assigning materials properties etc. Solver part involves solution of equations. ANSYS provides various solvers the total work consists for composites structure can be completed from design to final information as a result. Ansys program was used to calculate flexural strength value for epoxy resin before and after reinforced with different weight percentage from carbon nanofibers (0.1%, 0.2%, 0.3%, 0.4%, 0.5%, 0.6%, 0.7%, 0.8%, 0.9%, 1%). Specific Properties for both resin and fibers was input in database of ANSYS program, as well as standard shape of coupons and applied different amount of loads to make a theoretical emulation to experimental flexural test, and then draw the obtained data after applied the loads.

3. Result And Discussion

3.1 Flexural Test

Flexure test is the most common for polymers. Specimen deflection is usually measured by the crosshead position. In this experiment 3 point bending test was used as show in figure 4.

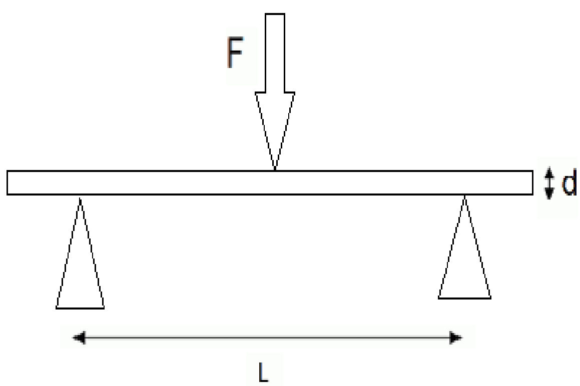

Figure 4. Shows the 2D of flexural testing

The flexural properties of the resin matrix composite with the reinforcement of carbon nanofiber in ten different ratios each ratio 5 coupons are fabricated and tested. The flexural strength and the maximum stress of the composites was estimated and compare with analytical value. The numerical comparison of the results is shown in table 2.

Table-2 The numerical comparison of the results

Sample	CNF 0.1% (Mpa)	CNF 0.2% (Mpa)	CNF 0.3% (Mpa)	CNF 0.4% (Mpa)	CNF 0.5% (Mpa)	CNF 0.6% (Mpa)	CNF 0.7% (Mpa)	CNF 0.8% (Mpa)	CNF 0.9% (Mpa)	CNF 1% (Mpa)
Experimental Flexural Strength MPa	3.242	4.414	5.830	8.011	10. 085	8.961	8.004	7. 051	6.263	5.107
Experimental Flexural Strength MPa	3.861	4.395	5.583	8.245	10.295	9.325	8.434	7.009	6.237	5.49
Error	0.619	0.019	0.247	0.234	0.21	0.364	0.43	0.042	0.026	0.383

The table 2 shows the percentage of error between the actual failure load and the simulated. The maximum error of the is due to the defects as motioned in the table 1, crack and cavity present on the coupon but all other coupons has minimum error percentage. Results revealed that flexural results for numerical analysis are better than experimental results. This deviation of results occurred due to manufacturing defects of composites like cavity, crack, porosity etc.

3.2 Ansys

Finite element Analysis is a numerical method of a complex system into very small pieces called elements. The engineering data and materials properties are required to analyze the prepared composite specimens so that we can create one model and use it for the analysis purpose. In ANSYS software the parameters for analysis purpose chosen were based on the matrix material and the reinforcement. Static structure and advanced composite tools were also selected for the purpose. The values of flexural strength and maximum stress values were determined experimentally. The element type used for ANSYS work was solid 8-node. Figure 5(a) to (k) shows the deformation and stress of FEA model for the coupons in 3 dimensional views respectively.

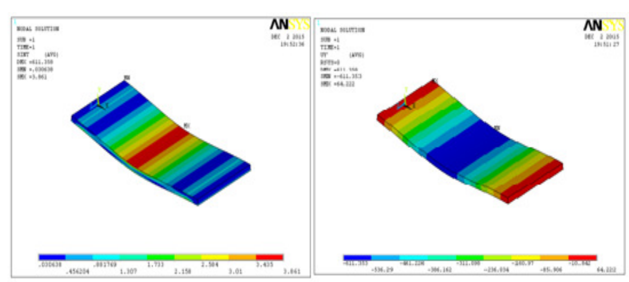

Figure 5 (a). 0.1 wt% CNF Analysis result

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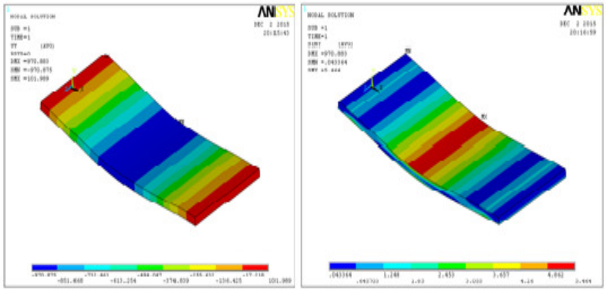

Figure 5 (b). 0.2 wt% CNF Analysis result

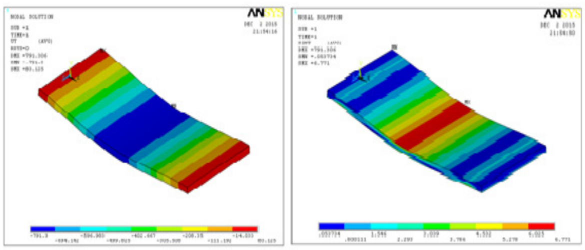

Figure 5 (c). 0.3 wt% CNF Analysis result

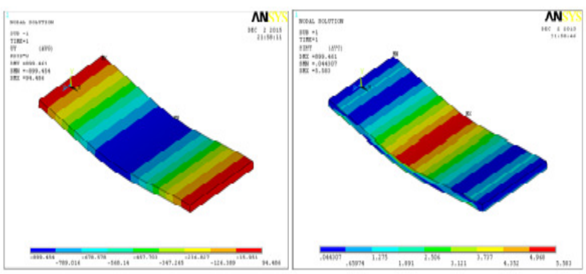

Figure 5 (d) . 0.4 wt% CNF Analysis result

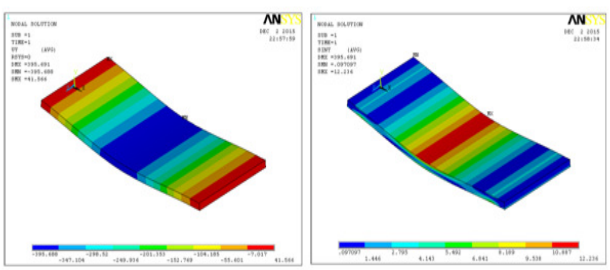

Figure 5 (e) . 0.5 wt% CNF Analysis result

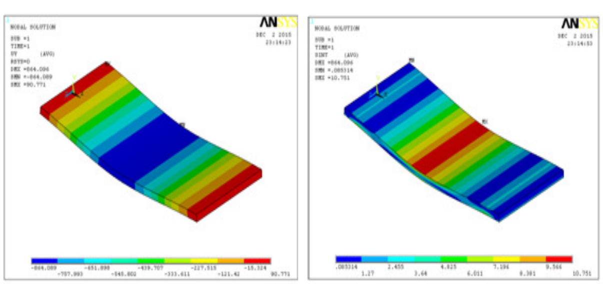

Figure 5 (f). 0.6 wt% CNF Analysis result

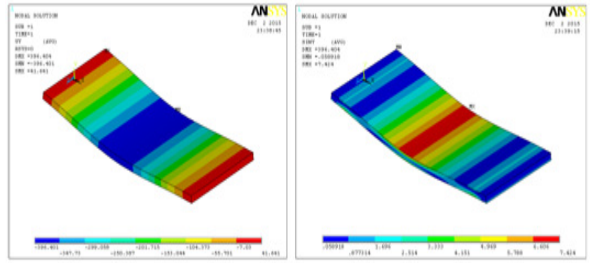

Figure 5 (g). 0.7 wt% CNF Analysis result

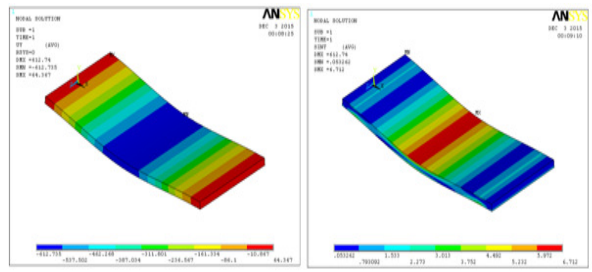

Figure 5 (h). 0.8 wt% CNF Analysis result

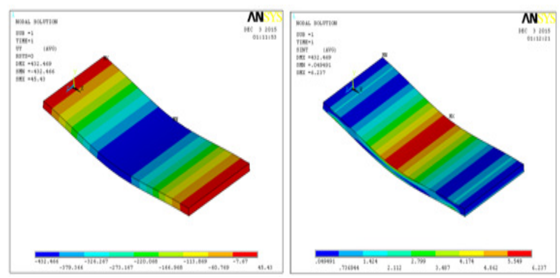

Figure 5 (i). 0.9 wt% CNF Analysis result

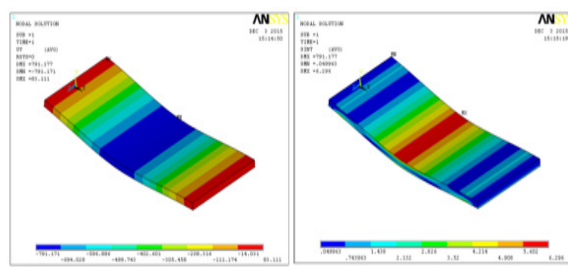

Figure 5 (j). 1 wt% CNF Analysis result

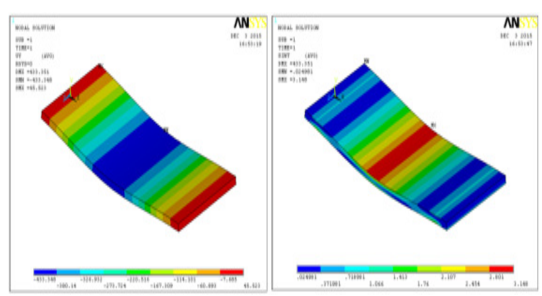

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Figure 5 (k). Pure epoxy resin Analysis result

4. Conclusion:

Test coupons were subjected to standard flexural 3 point bending test. The average flexural strength of all the readings of each specimen is considered in order to obtain the correct value of the flexural strength. The FEA analysis of mechanical properties of the Carbon nanofiber reinforced with epoxy in different ratios was reported and the results were summarized. The results obtained experimentally were compared with the simulation in ANSYS software. The experimental flexural load values and flexural load values from ANSYS were matched reasonably and validating the experimental results.

REFERANCE:

[1]. Gojny F, Wichmann M, Kopke U, Fiedler B and Schulte K. Carbon Nanotube-Reinforced Epoxy Composites: Enhanced Stiffness and Fracture Toughness at Low Nanotube Content, Composites Science and Technology, 64: 2363-2371: 2004.

[2]. Matzek MD. Polymeric carbon Nano Composites, physical properties and osteoblast Adhesion Studies, Dayton, OH, USA, University of Dayton, Master's Thesis.P53-54 : 2004.

[3]. Sohel R, Alagirusamy R. And Mangala J. Journal of Applied Polymer Science, 118(4): 2276 2283:2010.

[4]. Ma H, Zeng J, Realff ML, Kumar S and Schiraldi DA. Processing, structure and properties of Fibers from polyester/carbon nanofiber composites." Composites Science and Technology, 63(11): 1617-1628: 2003.

[5]. Yuanxin Z, Farhana P, Shaik J and Mallick P K. Improvement in mechanical properties of carbon fabric-epoxy composite using carbon Nano fibers, Journal of Materials Processing Technology, 198 (1-3): 445-453: 2008.

[6]. M. Joshi* and A. Bhattacharyya, 'Carbon Nanofiber Reinforced Carbon/Polymer Composite', 3:308-311:2004.

[7]. Lao, S.; Ho, W.; Ngyuen, K. & Koo, J.H. Flammability, mechanical, and thermal properties of polyamide nano composites. In Proceedings of SAMPE 2005, Seattle,WA, 2005.

[8] .Smith Jr. JG, Connell JW, Hergenrother PM, Ford LA, Criss JM, Transfer molding imide resins based on 2,3,3,4-biphenyltetracarboxylic dianhydride.Macromol. Symp. 199: 401: 2003.

[9]. E.P.DeGarmo, J.T. Black, and R.A. kohser, "Materials and processes in Manufacturing", 10th Edition, John Wiley & Sons, 2008.