Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 09, September - 2017

The Mechanical Properties of CF/Epoxy Resin Composite with Adding Different Types of CNTs

Hany Fouda
School of Chemistry and Environment
Beijing University of Aeronautics and Astronautics
Beijing, China.

Lin Guo
School of Chemistry and Environment
Beijing University of Aeronautics and Astronautics
Beijing, China.

***Abstract*—The main objective of this paper was to providing simple method for adding CNTs into CF/polymer composite and also to understand the effect of adding different types of carbon nanotubes (CNTs) on the elastic behaviors of textile based composites. The materials consist of three phases namely, carbon fibers fabric, Epoxy matrix and carbon nanotubes. Different types of CNTs were added separately with 1 % weight ratio of each type of used CNTs to CF/Epoxy resin matrix. A set of mechanical tests as tensile test, shear Beam Test and three point bending tests were performed. A damage initiation and cracks propagation in composite specimens were controlled. The experimental results show an increase in the mechanical performance of the composite with different values due to addition of different types of CNTs to CF/Epoxy resin matrix.**

Keywords—Carbon fiber; Epoxy resin; Carbon nanotubes; Composites; Mechanical properties.

I. INTRODUCTION

Many types of filler can be used with resin matrix composite materials but the most important one is Carbon fiber CF and this is because its excellent engineering properties, such as high specific stiffness and strength, performance to weight ratio, high thermal stability, high conductivity, corrosion resistance and self-lubrication. Most obviously, CF used in the structural application that needs weight reduction of the equipment as vehicles industries due to its high strength to weight ratio. CF reinforced resin matrix composites have a lot of applications as in aerospace applications, turbomachinery, for wind turbines applications in automotive energy systems, fuel cells, compressed gas storage and transportation, antistatic and electromagnetic shielding applications. the carbon fibers reinforced polymer matrix composites is widely used in automobile industries, aerospace, and marine during the last few decades due to their good engineering properties such as high specific strength and stiffness, lower density [1-5].

Due to the inertness of CF, improving at the fiber surface is needed in order to improve the interfacial bonding between fiber/matrix for effective stress transfer at the interface [6-7]. Liu and Kumar have studied the existing progress of carbon fiber structure, fabrication, and characterization including the addition of nanotubes in precursor fiber to improve the mechanical properties [8-10].

Carbon nanotubes (CNTs) have been widely used in enhancing composites for its large specific surface area, excellent mechanical properties, as well as good compatibility with the polymer [11-13]. Introducing CNTs to the surface of fibers to enhancement the interfacial properties of composites considered as a hot topic. So far, several methods have been developed to introduce CNTs to the fiber surface, such as chemical grafting and chemical vapor deposition. Both methods could effectively introduce CNTs on the surface of CFs with strong adhesion, but the excessive chemical treatments and the use of high temperature have hindered their practical application. Electrophoretic deposition is another efficient way to introduce and incorporate CNTs in composites. However, it was woven carbon fabric that was mostly used to receive CNTs, in which case CNTs were only deposited on part of the fiber surface rather than all surfaces. Besides, the complicated process also limits its application in industrial scale [14-18].

With comparison to above methods, sizing or coating fibers with CNT-containing sizing agent exhibit excellent advantages for their simplicity and low-cost and show a great potential application in industrial manufacturing of CNT/CF hybrid fibers [9-10]. Jianwei Zhang, Dazhi Jiang, Su Jua, Hua-Xin Peng, improved mechanical properties of composite material based on carbon fiber (CF) reinforced epoxy resin by adding a small quantity of multi-walled carbon nanotubes (MWCNTs). 1 wt. % MWCNTs were well dispersed in the epoxy resin and fiber filament wind process were used for manufacturing the CF prepregs. The hybrid MWCNTs/CF/epoxy composites were fabricated by laying up technique. Investigation applied on tensile properties, interlaminar shear strength (ILSS) and microstructures for the prepared composites [15-20].

In this work, a simple and clear method for addition of CNTs to the CF composite system was done. This technique depends on adding of CNTs to the CF/epoxy resin system through the two routes of the composite system (epoxy polymer and CF mat). In this research three types of CNTs (SWCNTs, DWCNTs and MWCNTs) was introduced separately to CF/Epoxy resin matrix system. The CNTs was introduced into CF and epoxy polymer separately in the first step. Then the CNTs/CF and CNTs/epoxy polymer were mixed together to get the CF/CNTs/Epoxy Resin Composite. Different types of CNTs with 1% weight ratios of each type of CNTs was added to CF/Epoxy resin composite as (SWCNTs, DWCNTs and MWCNTs) in order to study the effect of addition of different types of CNTs on the mechanical properties of CF/Epoxy resin composites.

II. EXPERIMENTAL WORK

A. Materials

In this research the used fiber was T300 PAN carbon fiber manufactured from apolyacrylonitrile precursor with moderate mechanical properties (strength; modulus) and with fiber yarn contains 3000 filaments purchased from Kunshan Samson composite material Co., Ltd, China. The polymer used in this study is epoxy resin system with two components A epoxy (EPON 828) cured with B polyamide (versamide 125) hardener. The used resin system purchased from Suzhou colorful stone composite materials Co, Ltd, China. The resin system was prepared in proportions of 3:1 by weight. Three types of CNT_S were used ($SWCNT_S$, $DWCNT_S$ and $MWCNT_S$) obtained from Aladdin Co., Ltd, China.

B. Epoxy system preparation

The used resin system is epoxy resin consists of two parts; part A (EPON 828) polymer and part B (versamide125) as curing agent. The calculated amount of part A were carefully weighed and then added the required amount of part B, then we stirring the mixture for 30 min using magnetic stirrer to prevent air trapping with low velocity rate then put in ultrasonic bath sonicator for 30 min to achieve good mixing.[13]. In case of addition CNT_S to CF based composite, CNT_S was added first to part A in suitable beaker with stirring for 30 min for to achieve homogenous mixture and for good distribution, then put in ultrasonic bath sonicator for 3 hours to achieve good distribution of CNT_S in epoxy, second step by adding part B to the mixture in ultrasonic bath sonicator for 30 min and in this case the epoxy called modified epoxy resin, the last step by use the matrix contain CNT_S with CF to produce composite material [21].

C. Composite sample preparation

In this paper the hand lay-up technique was used to fabricate the composite material samples. For good impregnation of carbon fiber with epoxy matrix roller and brush were used. First the epoxy resin was prepared as explained in paragraph 2.2. The CF mats treated first with acetone in order to eliminate the sizing.

In the case of sample (C) CF mat was cut in to adaptable size of 250×250 mm. the brush was used for coating the epoxy resin on the surface of CF. Then put and aligned the epoxy-coated fiber tape together layer above layer then the prepared composite was covered on both the sides with iron sheets and kept between the fixed and movable die of the compression molding machine under 5MPa pressure and 60 ^{0}C for 24 hours.

In case of other samples the half amount of CNT_S was added to epoxy resin as illustrated in section 2.2 to prepare modified epoxy resin and the other amount of CNT_S was dissolved in 100 ml ethanol and the mixture put in ultrasonic bath soincator for 1 hour then this mixture put in spray gun and sprayed on the surface of CF mat then the CF mat put in to an oven at 40 ^{0}C for 1 hour to evaporate the ethanol. The both modified CF mat and epoxy were ready to use the same procedure in case of sample (C) to prepare the other composite samples (CS, CD and CM).

D. Mechanical testing

The tensile test machine used in this research was universal testing machine (WDW-100), purchased from Fangrui Technology Co., Ltd. Changchun, China) which used to measure all mechanical properties for the prepared samples. An Interlaminer shear strength test sample with dimensions according to the standard (ASTM D 2344) was done. Flexural test (the three-point bending test) was done and processed according to ASTM D790 with specimen dimensions 12.7mm width, 200mm length and with span to thickness ratio = 32:1.The tensile test was done according to ASTM D3039 the sample specimen with 12.7mm width, 203mm length and with thickness depend on a number of layers was used for the tensile test. We calculated and reported the average value for five specimens of each sample. The Standard Flat shape for tensile specimens is shown in figure 1.

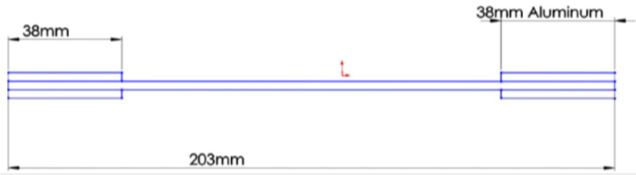

Fig.1. Standard Shape of tensile specimens.

III. RESULT AND DISCUSSION

A. Microstructure of the Used CNT_S

Three types of CNT_S were used in this research $SWCNT_S$, $DWCNT_S$ and $MWCNT_S$.TEM instrument was used to show the microstructure for the three types of CNT_S as shown below in figures 2, 3 and 4.

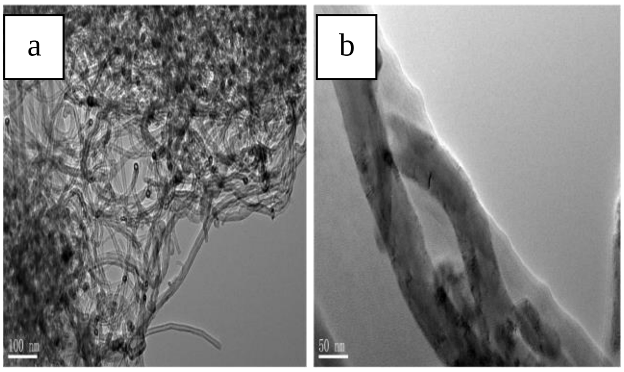

Fig.2. Microstructures of $SWCNT_S$ (a)resolution 100 nm(b) resolution 50 nm.

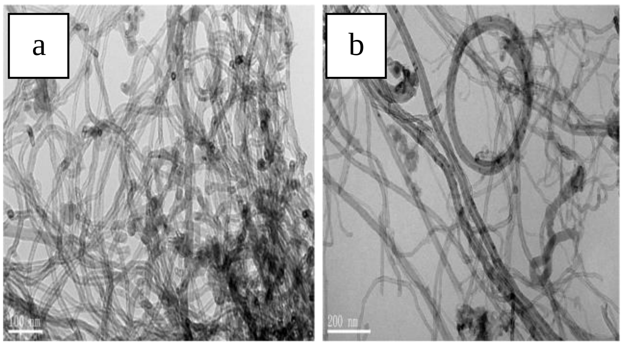

Fig.3. Microstructures of DWCNTS (a) resolution 100 nm (b) resolution 200 nm.

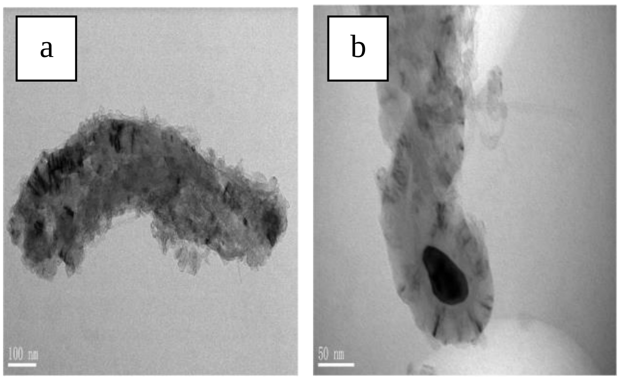

Figure 4 Microstructures of $MWCNT_S$ (a)resolution 100 nm(b) resolution 50 nm.

Figure 2 show TEM micrographs and microstructure of the used $SWCNT_S$ at two different resolutions 100 nm and 50 nm respectively. The figure show that the used $SWCNT_S$ consist from cylindrical tube with thin wall (single wall) and the CNT_S preferred to aggregate together as shown in figure 2 (a).

Figure 3 show TEM micrograph and microstructure of the used $DWCNT_S$ at two different resolutions 100 nm and 200 nm respectively. The figure show that the $DWCNT_S$ consist from cylindrical tube but the wall of the cylinder look more thick as it consist from double wall not single wall as shown in figure 3(a) and (b).

Figure 4 show TEM micrograph and microstructure of the used $MWCNT_S$ at two different resolutions 100 nm and 50 nm respectively. The figure show that the used $MWCNT_S$ look like cylindrical tube with very thick wall because it consist from multi wall tubes this means tubes inside tube inside tube and so on so the wall look thick. The figure also show that the length of the tube nearly about 600 nm.

B. Mechanical test results

The mechanical properties of the prepared samples were shown in figures 5, 6 and 7.The figures show that there are 4 composite samples were prepared. The first composite sample C is based on CF/ epoxy resin, the second composite sample CM is based on CF/ 1wt% $MWCNT_S$ epoxy resin, the third composite sample CD is based on CF/1wt% $DWCNT_S$/Epoxy resin, and the forth composite sample CS is based on CF/1wt% $SWCNT_S$/Epoxy resin.

From figure 5 the tensile strength of prepared composite samples can be seen. The experimental results show an increase in tensile strength of the composite sample due to addition of 1wt% CNT_S. The value of increase is change according to the type of added CNT_S. . The results show that the tensile strength of sample C<CM<CD<CS by 17.65%, 1.83% and 11.85% respectively.

From figure 6 the flexural strength of prepared composite samples can be seen. The experimental results show an increase in flexural strength of the composite sample due to addition of 1wt% CNTS. The value of increase is change according to the type of added CNTS. The results show that the flexural strength of sample C<CM<CD<CS by 69 %, 5.4% and 18.9 % respectively.

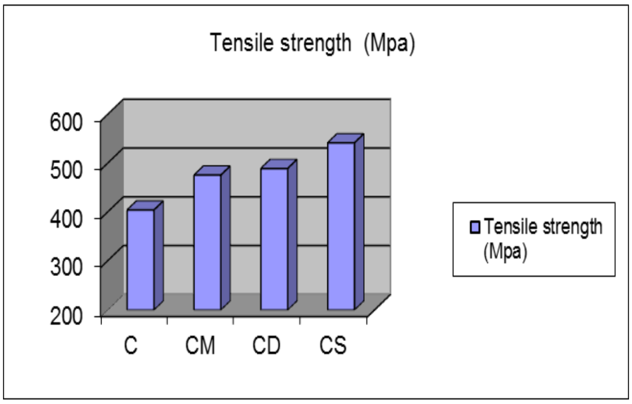

Fig.5. Tensile strength results

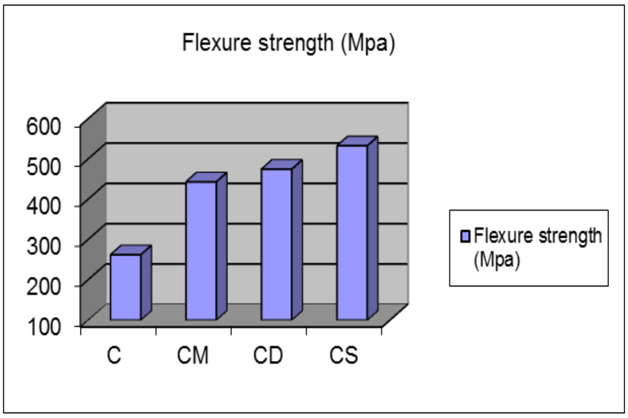

Fig.6. Flexural strength results

From figure 7 the interlaminer shear strength of prepared composite samples can be seen. The experimental results show an increase in interlaminer shear strength of the composite sample due to addition of 1wt% CNT_S. The value of increase is change according to the type of added CNT_S. The results show that the interlaminer shear strength of sample C<CM<CD<CS by 70%, 5.4%, and 14% respectively.

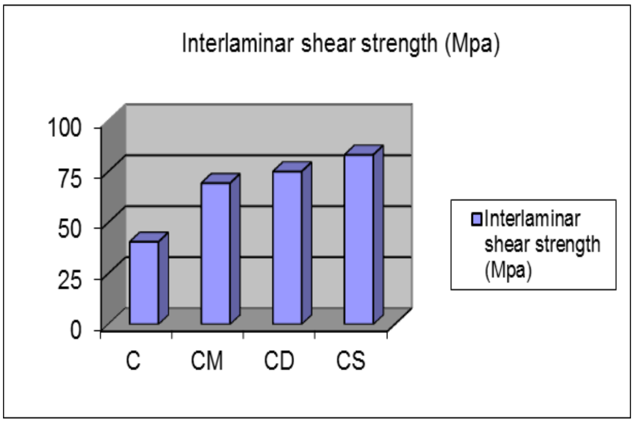

Fig.7. Interlaminer shear strength results.

The enhancement in mechanical properties of the composite samples due to addition of 1% CNT_S can be related to enhancement of bonding between CF and epoxy and improve matrix-fiber interfacial interactions so improve the mechanical properties as tensile ,flexural and interlaminer shear strength. The difference in enhancement value can be related to the difference in the microstructure of each type of used CNT_S.

IV. CONCLUSION

The introduction of CNT_S to the CF/epoxy resin matrix is one of the most effective methods for improving and enhancing the interface between CF and epoxy resin and so improving the structural properties as mechanical characteristics of the CF/epoxy resin composite. It was found that the method of adding CNT_S into the CF composite system play important rule for increasing the interface bonding between CF and epoxy polymer which leads to increase the mechanical properties of the prepared composite. The results show that the mechanical properties of C<CM<CD<CS as flexural strength of sample C<CM<CD<CS by 69 %, 5.4% and 18.9 % respectively. This is because adding of CNT_S to the CF/epoxy resin composite improves the epoxy bonding and the interface bonding between CF and epoxy so improve the mechanical properties. The difference in enhancement value can be related to the difference in the microstructure of each type of used CNT_S.

ACKNOWLEDGMENT

We would like to extend thanks to the people whose contributions helped make this research and the group that we worked closely with. They have always been there to answer questions or give advice when we have difficulties. Also, we would like to thank School of Chemistry and Environment, Beijing University of Aeronautics and Astronautics to provide the instruments and its technical support.

REFERENCES

[1] Schwartz M M 1992 Composite Materials Hand Book McGraw-Hill.
[2] Whitcomb J D 1988 Composite materials testing and design ASTM.
[3] Peters ST 1998 Hand book of composites CHAPMAN&HALL.
[4] Soutis C 2005 Fiber reinforced composites in aircraft construction Prog Aerospace Sci 41 143–51.
[5] Pavia J M F, Santos A N, Rezende M C 2009 Mechanical and morphological characterizations of carbon fiber fabric reinforced epoxy composites used in aeronautical field Mater Res 12(3) 367-374.
[6] Mallick P K 2008 Fiber reinforced composites: material, manufacturing and design 3rd Ed. New York: CRC Press.
[7] Edie D D, McHugh J J 1999 High performance carbon fibers In: Burchell TD, editor. Carbon materials for advanced technologies, Pergamum p. 119–38.
[8] Liu Y, Kumar S 2012 Recent progress in fabrication, structure, and properties of carbon fibers Polym Rev 52(3–4) 234–58.
[9] Sharma M, Gao S, Mäder E, Sharma H, Wei L Y, Bijwe J 2014 Carbon fiber surfaces and composite interphases Composites Science and Technology 102 35–50.
[10] Pavia M C, Bernardo C A, Nardin M 2000 Mechanical, surface and interfacial characterization of pitch and PAN-based carbon fibers Carbon 38(9) 1323-37.
[11] Takeichi, Furukawa N 2015 Epoxy Resins and Phenol-Formaldehyde Resins Reference Module in Materials Science and Materials Engineering Polymer Science: A Comprehensive Reference 5 723-751.
[12] Chung D D L 1994 Carbon Fiber Composites Butterworth-Heinemann.
[13] Gipson R F Principles of composite materials mechanics McGraw-Hill.
[14] Zhang H, Zhang Z, Breidt C 2004 Comparison of short carbon fiber surface treatments on epoxy composites Institute for Composite Materials, University of Kaiserslautern, and Erwin Schrodinger strasse 58.
[15] Zhang J, Ju S, Jiang D, Peng H X 2013 Reducing dispersity of mechanical properties of carbon fiber/epoxy composites by introducing multi-walled carbon nanotubes Composites Part B: Engineering 54 371–376.
[16] Magdy W 2004 Production technology of composite materials based on polymeric matrices Master, MTC, Egypt.
[17] Li X, Han X, Tan Y, and Xu P 2007 Preparation and microwave absorption properties of Ni-B alloy- coated Fe3O4 particles Journal of alloys and compounds 240-245.
[18] Li X , Yang H, Fu W, Liu S, Zhu H, and Pang X 2006 Preparation of low-density super paramagnetic microspheres by coating glass micro balloons with magnetic nanoparticles Materials science and Engineering: B 135 38-43.
[19] Rawal S and Brantley J 2013 Development of Carbon Nanotube-based Composite for Spacecraft Components In Recent Advances in Space Technologies (RAST), 2013 6th International Conference on. IEEE 13-19.
[20] Zhao Z, Teng K, Li N, Li X, Xu Z, Chen L, Niu J, Fu H, Zhao L, Liu Y 2017 Mechanical, thermal and interfacial performances of carbon fiber reinforced composites flavored by carbon nanotube in matrix/interface Composite Structures 159 761–772.
[21] Fouda H, Guo L and Elsharkawy K 2017 Preparation and Characterizations of Composite Material Based on Carbon Fiber and Two Thermoset Resins MATEC Web of Conferences 88 02002.