Effect of Adding Multiwall Carbon Nanotubes on the Mechanical Properties of Carbon Fiber Based Polymer Composites

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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 multiwall carbon nanotubes (MWCNTs) additives on the elastic behaviors of textile based composites. The materials consist of three phases namely, carbon fibers fabric, Epoxy matrix and carbon nanotubes. Different weight ratio of MWCNTs was used (0% as reference, 0.5%, 1%, 1.5%, 2% and 2.5%). 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 up to 2% of MWCNT additives. However, beyond this value, the material strength shows a significant decay investigation.

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 MWCNTs to the CF composite system was done. This technique depends on adding of MWCNTs to the CF/epoxy resin system through the two routes of the composite system (epoxy polymer and CF mat). In this research MWCNTs was introduced into CF and epoxy polymer separately in the first step. Then the MWCNTs/CF and MWCNTs/epoxy polymer were mixed together to get the CF/MWCNTs/Epoxy Resin Composite. Different weight ratios of MWCNTs was added to CF/Epoxy resin composite as 0%, 0.5%, 1%, 1.5%, 2% and 2.5% weight ratio of MWCNTs in order to study the effect of addition of MWCNTs on the mechanical properties of CF/Epoxy resin composites.

Experimental Work

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. MWCNTs with a particle size 20-45 nm obtained from Aladdin Co., Ltd, China.

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 MWCNTs to CF based composite, MWCNTs 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 MWCNTs 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 MWCNTs with CF to produce composite material [21].

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 the previous paragraph. The CF mats treated first with acetone in order to eliminate the sizing. In the case of sample C1 CF mat was cut in to adaptable size of 250×250 mm. the brush was used 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 for 24 hours. In case of other samples the half amount of MWCNTs was added to epoxy resin as illustrated in the previous paragraph to prepare modified epoxy resin and
the other amount of MWCNTs was dissolved in 100 ml ethanol and the mixture put in ultrasonic bath soinicator for 1 hour then this mixture put in spray gun and sprayed on the surface of CF mat then the CF mat put in oven at 40 °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 C1 to prepare the other composite samples.

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.

Figure 1. Standard Shape of tensile specimens.

Result and Discussion

The mechanical properties of the prepared samples were shown in figures 2, 3 and 4. The figures show that there are 6 composite samples were prepared. The composite sample C1 is based on CF/epoxy resin, the second composite sample C2 is based on CF/0.5wt% MWCNTs/Epoxy resin, the third composite sample C3 is based on CF/1wt% MWCNTs/Epoxy resin, the forth composite sample C4 is based on CF/1.5wt% MWCNTs/Epoxy resin, the fifth composite sample C5 is based on CF/2wt% MWCNTs/Epoxy resin and the last composite sample C6 is based on CF/2.5wt% MWCNTs/Epoxy resin. From figure 2 the tensile properties of prepared composite samples can be seen. The experimental results show an increase tensile strength of the composite up to 2 wt% of CNT additives. However, beyond this value, the tensile strength shows a significant decay. The results show that the tensile strength of sample C1/C2/C3/C4/C5 by4%, 13%, 8% and 11.7% respectively. While in case of sample C6 the tensile strength decrease and the result show that tensile strength of C6/C1 by 2.5%

Figure 2. Tensile strength results.

Figure 3 shows the flexural strength results of the prepared samples. The experimental results show an increase in flexural strength of the composite up to 2 wt% of MWCNTs additives. However, beyond this value, the flexural strength shows a significant decay. The results show that the Flexural strength of sample C1/C2/C3/C4/C5 by25.7%, 34%, 12.7%and 10% respectively. The result show that the flexural strength of C6 decreased by 3% than that of C1.
Figure 3. Flexural strength results.

Figure 4 shows the interlaminer shear strength of the prepared composite samples. The experimental results show an increase in interlaminer shear strength of the composite up to 2 wt% of MWCNTS additives. However, beyond this value, interlaminer shear strength shows a significant decay. The results show that the interlaminer shear strength of sample C1<C2<C3<C4<C5 by 23%, 38%, 40% and 19% respectively. The result show that the flexural strength of C6 decreased by 6.5% than that of C1.

The enhancement in mechanical properties of the composite samples up to 2 wt% of MWCNTS additives This is because the addition of MWCNTS through two routes at the same time (via epoxy resin and CF mat) increase the possibility for good mixing and good dispersion of MWCNTS into the CF/epoxy resin composite system and this lead to stronger of resin matrix and improve matrix-fiber interfacial interactions so improve the Interlaminer shear strength. The significant decay occur at addition 2.5wt% of CNTs may be due to the volume of CNTs at this wt% is very large and so it is difficult to achieve homogenous mixing of CNTS and this lead decrease the bonding between CF and polymer and so decrease the mechanical properties.

**Conclusion**

The introduction of CNTS 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 CNTS 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 C1<C2<C3<C4<C5 as flexural strength C1<C2<C3<C4<C5 by 25.7%, 34%, 12.7% and 10% respectively. This is because adding of MWCNTS to the CF/epoxy resin composite improves the epoxy bonding and the interface bonding between CF and epoxy so improve the mechanical properties.

**References**