Effects of Multi-Walled Carbon Nanotubes on The Mechanical Properties of Glass/Polyester Composites

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Abstract

Excellent mechanical properties of carbon nanotubes (CNTs) make them outstanding candidate reinforcements to enhance mechanical properties of conventional composites. The glass/polyester composites are widely used in many industries and applications. Improving the mechanical properties of such composites with addition of CNTs can increase their applications. In this research, multi-walled carbon nanotube (MWCNT) at different weight ratios (0.05, 0.1, 0.3, 0.5 wt.%) were added to chopped strand mat (CSM)/Polyester composites. Mechanical stirring with the aid of sonication technique were used to achieve a good dispersion state of MWCNTs in the polymeric matrix. The specimens were fabricated by the hand lay-up method. It is assumed that a high level of dispersion in the preparation stage may lead to better mechanical properties of the nanocomposite. Scanning electron microscopy (SEM) was employed to determine the dispersion state of carbon nanotubes in the matrix. Mechanical tests (tensile and flexural) were performed in order to evaluate the effects of adding MWCNT on CSM/Polyester composites. The results exhibit improvements in flexural strength while the values of tensile strength do not show significant changes. Although addition of filler at all above ratios increased the flexural strength, introducing only 0.05 wt.% MWCNT into the CSM/Polyester composites enhanced the flexural strength by 45%. Moreover, improvements in Young's and flexural moduli were observed.

Keywords: Multi-walled carbon nanotube, Chopped strand mat, Polyester, Mechanical properties

1. Introduction

Since the discovery of carbon nanotubes by Ijima in 1981 [1], they play an important role in reinforcing the conventional composites. High physical and mechanical properties [2] of this form of carbon atoms make them ideal candidates for fabrication of nanocomposites. In the recent years, CNTs were added to polymeric matrices in order to improve various properties of the resulting composite such as mechanical and electrical properties [3-6]. CNTs are also used to enhance the properties of fiber reinforced composites and fabricate multi scale composites. Some different methods can be employed for this purpose such as growing aligned CNTs on the fibers surfaces [7], or disperse CNTs in the matrix and use the reinforced matrix to produce multi scale composites [8].

Glass/Polyester composites are one of the most common and conventional composites used in various fields of applications. Chopped strand mat/polyester composites, due to low price and relatively good properties, have a wide range of application in industries. Composite structures such as turbine blades or composite super structures are examples of using CSM/polyester composites. Although there are various researches on nano reinforcing of fiber composites [7-10], only a few investigations were performed to reinforce this type of composites.

In the present study, the effect of adding multi-walled carbon nanotube (MWNT) at different weight ratios on the mechanical properties of CSM/polyester composites has been investigated. Mechanical stirring and sonication technique were employed to achieve good dispersion state of nanotubes in polyester resin. Tensile and flexural tests were performed in order to find out the effects of MWNTs on the strengths and moduli in

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tension and bending. Scanning electron microscopy (SEM) was used to image the dispersion state of nanotubes in polyester matrix. Moreover, SEM images show the state of nanotubes on the glass fibers in the resulting composites.

2. Experimental and Procedure

2.1. Materials

CVD grown MWNTs were supplied by Io-Li-Tech Co. (Germany) and have diameters between 10 to 20 *nm* and lengths in the range of 5-15 *µm*. Fig.1 shows a SEM image of as supplied nanotubes. Glass chopped strand mat with density of 450 kg/m^2 and unsaturated Polyester resin (Boytec Co. Turkey) were employed to fabricate fiber reinforced composites. Curing process was performed by addition of Cobalt (8%) and MEKP (Butanox M60) as recommended by the manufacturer.

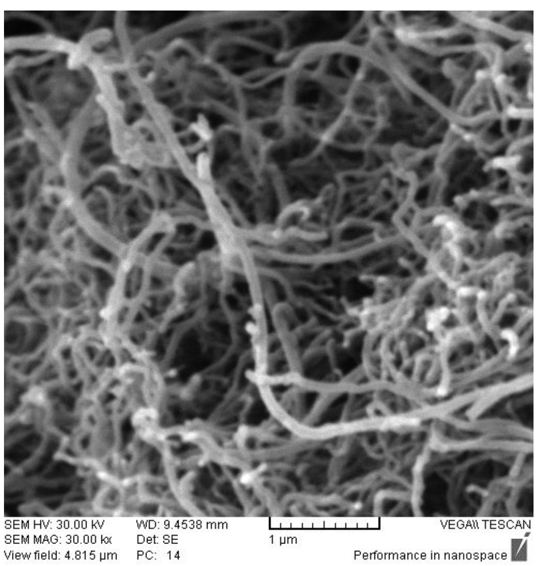

Fig. 1. SEM image of supplied MWCNT**.**

2.2. Preparation method

MWNTs at low weight ratios (0.05, 0.1, 0.3, 0.5 *wt.%*) were added to polyester resin and were initially mixed by mechanical stirrer for 20 *min* at 2000 *rpm*. Then the mixture was sonicated by 14 *mm* diameter probe sonicator Hielscher UP400S (Germany). The output power (200 *W*) and sonication time (45 *min*) were applied to obtain sonication energy of 1 *kJ/g* of mixture as sonication energy should be as much as it can break the agglomerations and disperse the particles in the mixture [11]. However, higher sonication energy leads to damage the CNTs which might decrease their properties. After dispersion of nanotubes in the polyester resin, conventional hand lay-up method was employed to fabricate composite sheets. The weight fraction of CSM was 50 wt.% (38% volume fraction).Then, each sheet was cut into pieces with proper dimensions for tensile and flexural tests according to standards.

2.3. Characterization

Tensile and flexural tests were performed according to ASTM D3039 [12] and ASTM D790 [13] respectively to evaluate the effects of adding MWCNT into the polyester by using universal testing machine Santam STM-150. Tescan Vega II electron microscope was used to investigate the fracture surface and dispersion state of MWNTs.

3. Results and Discussion

Figs. 2 and 3 present the results of tensile and flexural strengths of CSM/ MWNT/ polyester composites. According to the reported results, tensile strength does not show any significant improvement by adding MWCTNs.

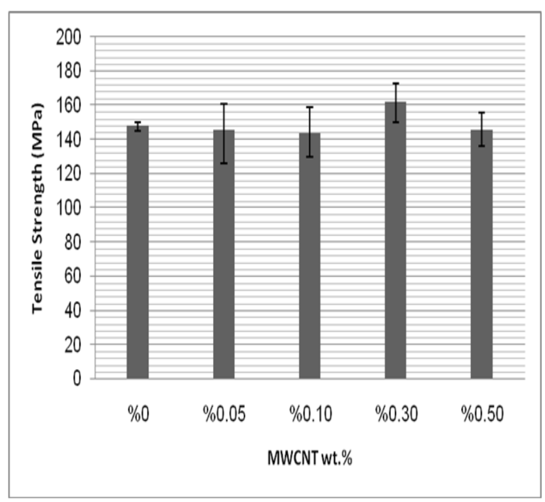

Fig. 2. Tensile strength of CSM/MWNT/polyester.

Fig. 3 shows that by adding only 0.05 *wt.%* MWCNT, flexural strength of CSM/polyester composites is enhanced by 45%. Increasing

MWNT weight ratios has no more positive effect on the flexural strength although the

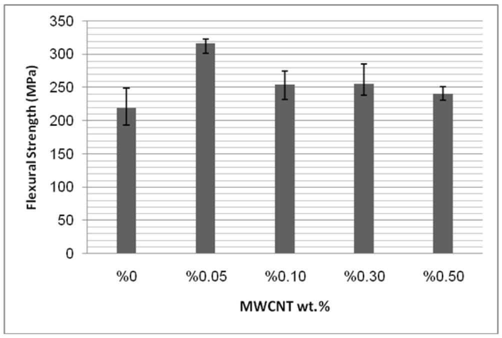

Fig. 3. Flexural strength of CSM/MWNT/polyester**.**

results are still higher than pure resin. Figs 4 and 5 show the tensile and flexural moduli of the reinforced composites.

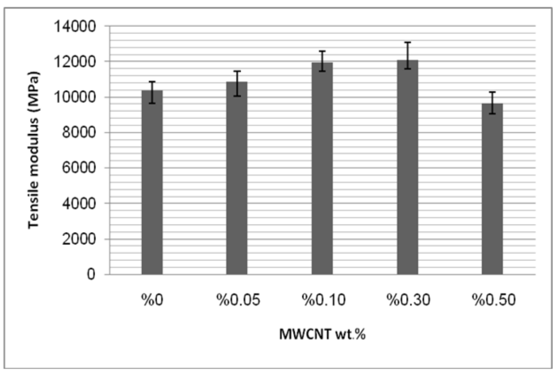

Fig. 4. Tensile modulus of CSM/MWNT/Polyester**.**

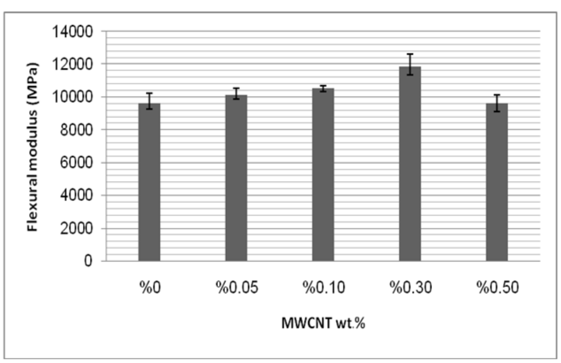

Fig. 5. Flexural modulus of CSM/MWNT/polyester**.**

According to the results, introducing MWCNT into the polyester resin demonstrates an ascending trend for both tensile and flexural moduli up to 0.3 wt.%, where reaches to a peak, and subsequently falls at 0.5 wt.%. The results might indicate that effect of tensile property in comparison with compression property is probably more dominant in flexural properties. This is why both diagrams show similar trends. Fig. 6 shows SEM image of dispersion state of MWCNT at 0.05 wt.% in the polyester resin.

As shown in Fig. 6, MWCNT were fully dispersed in polyester and thus improved mechanical properties of CSM/polyester composites. However, at higher weight fractions of nanotubes (0.5 *wt.%*), there were some agglomerations which were the reason that caused stress concentration and thus decreased the mechanical properties of the nanocomposites (Fig. 7).

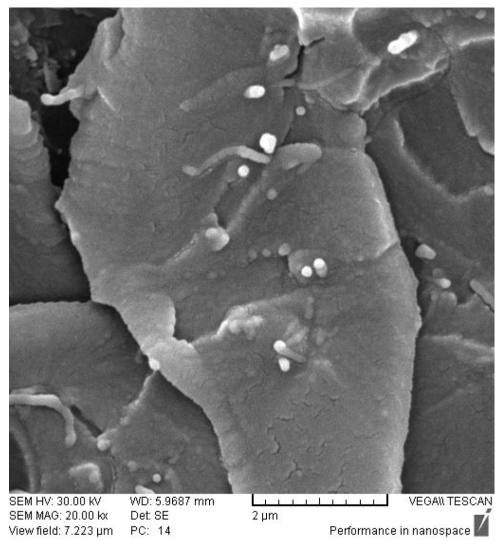

Fig. 6. Image of fracture surface of a sample containing 0.05 *wt.%* MWCNT.

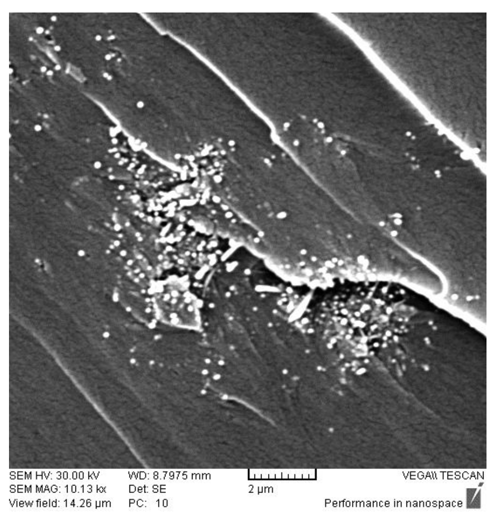

Fig. 7. MWNT agglomeration in a sample containing 0.5 *wt.%* MWNT.

4. Conclusions

Multi-walled carbon nanotubes at various contents namely 0.05, 0.1, 0.3, 0.5 *wt.%* were added to polyester resin and mechanical properties of the resulting nanocomposites were investigated. The results show that 45% enhancement in flexural strength of CSM/polyester at 0.05 *wt.%* MWCNT was achieved. Moreover, tensile and flexural moduli at 0.3 *wt.%* MWCNT were improved by 18% and 24% respectively. Also, it was seen that at higher weight ratios of MWCNT (0.5 *wt.%*) degradation of mechanical properties occurred. The main reason of this phenomenon is due to agglomeration of nanotubes that acts as stress concentration.

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