Influence of multiwall carbon nanotubes in mechanical properties of E-glass/epoxy resin/jeffamine-D400 composites

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ABSTRACT

Polymer nanocomposites reinforced with carbon nanotubes have been attracted by many researchers. The properties of nanocomposites depend greatly on the chemistry of polymer matrices, nature of nanofillers and the way in which they are prepared. Properties of epoxy resin have a significant influence on the mechanical properties of the nanocomposites. In this paper the effect of matrix hardness on the mechanical properties of the carbon nanotubes reinforced epoxy composite has been studied and an experimental investigation of the effect of nanotubes on the mechanical properties of the composites was reported. In this study, epon-828 and jeffamine-D400 is used. Multiwall carbon nanotubes/epoxy resin composites have been fabricated and the mechanical properties of the composite with different weight percentages of nanotubes have been obtained. A sonication technique was used to disperse nanotubes in epoxy matrix. Particular attention is paid on the structure property relationship of such novel high performance polymer nanocomposites when the matrix is reinforced with E-glass. The results have shown that ultimate stress and strain for different percentage of nanotubes is increased.

Keywords: multiwall carbon nanotubes, mechanical properties, polymer matrix, nanocomposite, E-glass

1 INTRODUCTION

Composite laminates are a valuable option to conventional materials due to their high specific mechanical properties, i.e. stiffness-to-weight and strength-to-weight. As a result, composite laminates have become widely spread into used in primary structural components in aircrafts, modern vehicles and Light-weight structures.

Carbon nanotubes have a number of properties that make them attractive for use in a broad spectrum of applications, especially as reinforcement in nanocomposites [1]. There are two kinds of carbon nanotubes: single-walled carbon nanotubes (SWNTs) and multi-walled carbon nanotubes (MWNTs). They can be produced in various ways such as arc discharge, laser ablation, solar energy, molten salt electrolysis and chemical vapor deposition (CVD). The nanotubes are often with more or less impurity depending on the synthesis method used. The SWNTs are often in bundles of tens to hundreds of single SWNT. The MWNTs were reported to have lower mechanical performance than the SWNTs, but can be produced in much larger quantity and at a lower cost.

Unique mechanical properties combined with high aspect ratios and low density render carbon nanotubes attractive for a new generation of engineering composites, often termed nanocomposites [4]. In the field of polymer-based nanocomposites, significant mechanical improvements have recently been obtained using thermoplastic and elastomer matrices [2]. As an example, a 80% improvement in tensile modulus was obtained when thermoplastic poly vinyl alcohol (PVA) was mixed with only 1 wt. % nanotubes [5]. In another work, an initial modulus 3-fold increase was obtained with 1 wt. % addition of single wall carbon nanotubes (SWNTs) into an RTV silicone rubber matrix at low (<10%) strain [5]. However, the effective reinforcement by carbon nanotubes of thermosetting polymers, such as the epoxy resins favored in aerospace and other industries, still presents great challenges.

While there is much debate as to the nature of the polymer morphology and property at the interface, it is clear that it plays a major role in the mechanical reinforcement process.

2 NANOCOMPOSITE SYNTHESIS AND EXPERIMENTS

The nanocomposite prepared for this investigation is a E-glass/epoxy that reinforced with different percentage of carbon nanotubes. The resin system was chosen owing to its long gel time

The E-glass fiber has a plain-weave woven fabric configuration with density of 200 g/m2. The E-glass/epoxy nanocomposite is a laminate with 12 layers. This type of laminate configuration is prepared using a hand lay-up which leads to an average thickness of 2 millimeter.

The amount of nanotubes exfoliated into the epoxy system, in weight, is 0.5%, 1% and 1.5%, respectively. The carbon nanotubes properties are 10 to 20 nanometer and length of 5 to 15 micrometer with purity more than 95 percent.

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The exfoliation process can be done by direct mixing, sonication mixing, shear mixing or a combination of sonication and shear mixing. In our case, the nanotubes exfoliation process is performed by sonication, in other words, the carbon nanotubes are mixed to hardener and later were on the ultrasonic wave. In the first step, sonication procedure is performed up to the formation of a homogeneous mixture (figure 1). During the second step epoxy is added to the hardener and then mixed with mechanical mixer.

Figure 1: sonication machine (Impact Mechanics Laboratory-TMU)

The largest numbers of reinforced plastics composite products are produced by the hand lay-up process. A few examples of this processes uses are: boats, portable toilets, picnic tables, car bodies, diesel truck cabs, hard shell truck bed covers and air craft skins and interiors. The hand lay-up process is labor intensive plus the plastic resins produce toxic fumes requiring well ventilated facilities and protective equipment for workers. And, since the workers seem to want to be paid more when around toxic things, they may want more pay. Hand lay-up parts can consist of any size or configuration. Moreover, the process does not require any special tools. So in this study, hand lay-up process has been used. By regarding 12 layer of woven glass fiber, the samples are created.

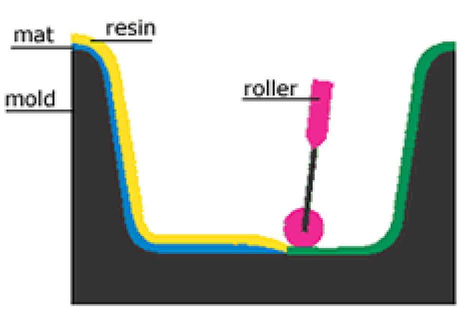

Figure 2: hand lay-up process

After molding, samples cured in oven to reach high mechanical properties. Weight pressure was used for having the same thickness in samples in curing time. After curing process the samples lost temperature in oven to prevent thermal stress. According to standard, the samples were cut with water jet method.

Once the E-glass/epoxy-nanotubes are prepared, the tensile test of Iso 527-4 has been used. The testing specimen is described by the schematic diagram represented in Figure 3.

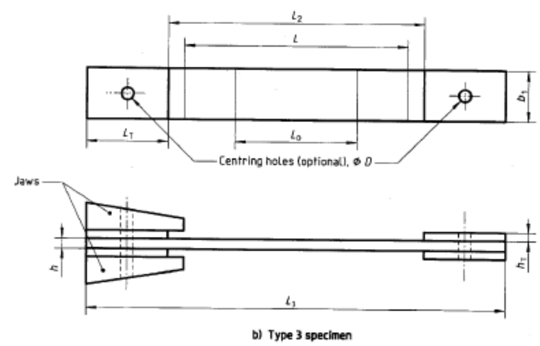

Figure 3: Iso 527-4 characteristic [3]

The prepered speciments for four persentage of nanotubs are shown in figure 4. In this figure can be seen that the effect of multiwall carbon nanotubes on the color of the speciments. By addeding carbon nanotubes, color is changed to black for all persentages.

Figure 4: the prepared speciments

3 RESULTS AND DISCUSSION

Tensile test results are shown in figure 5. Because of epoxy matrix is a brittle polymer, so ultimate stress, maximum stress and yield stress are same. As can be seen, for different percentage of carbon nanotubes, mechanical properties such as ultimate stress and toughness have increased.

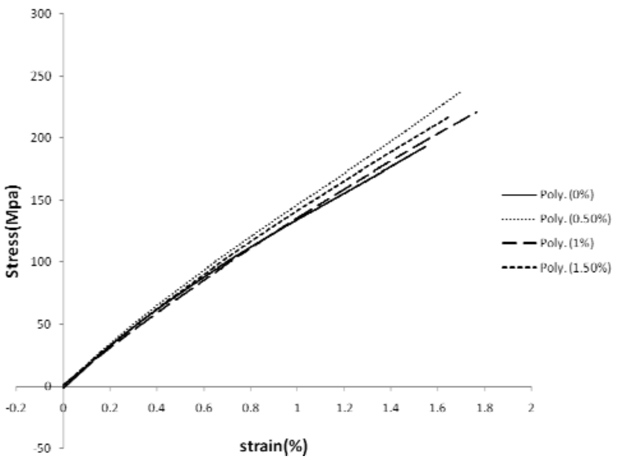

Figure 5: stress strain curvature for different nanotubes percentage

The results of stress strain curvature are listed in table 1. Ultimate strain is increased for all carbon nanotubes reinforced. The maximum value is for one weight percentage.

	Module	Ultimate Strain	Ultimate Stress
0%	15.77	1.547692	194.0019
0.50%	16.66	1.704978	245.0771
1%	15.19	1.763714	218.9157
1.50%	16.0	1.650884	217.374

Table 1: mechanical properties from tensile test

Ultimate stresses of different samples are compared in figure 6. Increase in the ultimate stress by addition carbon nanotubes is observed. The highest value is for 0.5% sample. In this case ultimate stress 26.3% increased. There are 12.8% and 12% increase For 1 and 1.5 percentage samples.

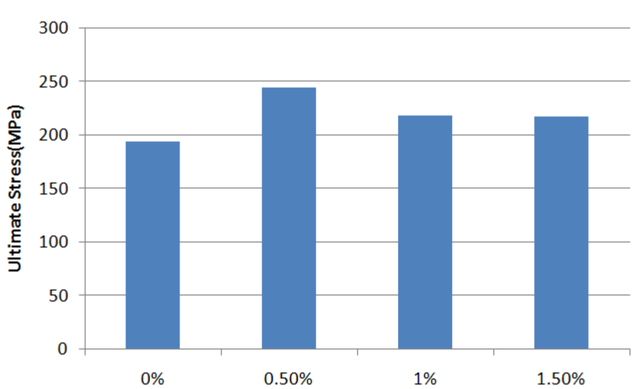

Figure 6: enhanced ultimate stress for different cases

Figure 7 show ultimate strain for four speciments. It can be seen the ultimate strain is increced for all speciments. The great influence is for 1 persentage carbon nanotube pesentage.

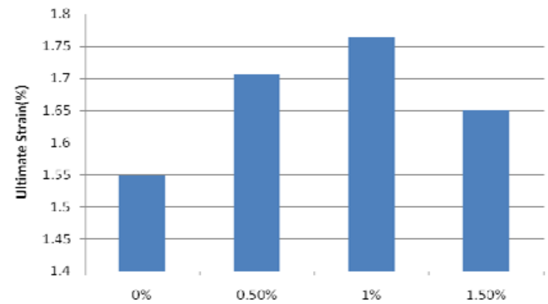

Figure 7: ultimate strain for different persentages

In nanocomposites containing nanotubes, physical contact at the molecular scale can be investigated as a main factor in the resistance of composite. While we can gain to the main ability of carbon nanotubes that force can be transferred from epoxy matrix to nanotubes and vice versa. So a good contact among materials has effective role in mechanical properties of nanocomposite. By increasing contact between nanotubes and matrix, more force transfer from matrix to nanotubes. According to high strength and modules of nanotubes, more force transferring to nanotubes can cause improvement of nanocomposite.

Distribution of nanotubes is one of the main factors that has important role in the properties of nanocomposite. Distribution of nanotubes in epoxy prevents from distortion of polymer. Cohesion of nanotubes can also cause crack and decreasing of mechanical properties.

4 CONCLUSION

The effect of multiwall carbon nanotubes into glass fiber/epoxy composite was investigated. By considering of three weight percent of nanotubes, the mechanical properties was compared. By adding carbon nanotubes, some mechanical properties such as ultimate stress and ultimate strain and toughness increased. The maximum value for ultimate stress is for 0.5 percentages of nanotubes. The maximum toughness is for 0.5 percentages of carbon nanotubes, too. Ultimate strain increase for every three persentages of carbon nano tubes.

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