STRAIN RATE EFFECT ON THE MECHANICAL PROPERTIES OF CARBON NANOTUBE/EPOXY COMPOSITES

Yi-Ming Jen [1], **Chien-Yang Huang** [2], **Pei-Ling Guo** [2], **and Yung-Chuan Wang** [2]

[1] Department of Mechanical and Mechatronic Engineering, National Taiwan Ocean University, No. 2, Pei-Ning Rd., Keelung 20224, Taiwan

[2] Department of Mechanical Engineering, Chung Hua University, No. 707, Sec. 2, Wufu Rd., Hsinchu 30012, Taiwan

Introduction

The carbon nanotubes (CNTs) have been considered as effective fillers employed in the polymer materials to reinforce the mechanical properties because of their high stiffness and strength. Many efforts have been made to study the relationship between the CNT contents employed in the polymer-based composites and the corresponding mechanical properties [1-6]. These mechanical properties used in evaluation of the reinforcement effects of CNTs were frequently obtained using the static tensile or flexural tests, and the addition of CNTs was found to significantly enhance the mechanical properties of the composites, such as the tensile moduli, ultimate strengths, and elongations. However, the strain rate effect on the mechanical properties of the CNT/polymer composites has never been studied. The mechanical properties of most traditional engineering materials are sensitive to the strain rate. These materials present brittle-like properties when high strain rates are employed in the tensile tests. Whether this observation is also valid for the CNT/epoxy composites is questionable. Furthermore, in some practical applications, the in-service strain rate was quite different with that utilized in the quasi-static tests. The mechanical property data under different strain rates are necessary for future design and usage of this innovative material. Therefore, in the present study, three different strain rates are employed in the static tensile tests for the CNT/epoxy composites to experimentally study the strain rate effect on the tensile properties of the nanocomposites. The CNT content is another variable considered in the experimental program to evaluate the relationship between the strain rate effect and the CNT contents of the studied composites.

Experimental Procedure

The diameter and length of the employed Multi-walled CNT (MWCNT) in the study are 30-50 and 10-200 nm, respectively. The CNTs were mixed with nitric acid at 120°C for 1 h. The solution was then filtered using a vacuum system associated with the PVDF filter. The CNTs was added into the deionized water, and dispersed using mechanical stirring and sonication. The procedures of cleaning, dispersion and filtering were repeated for 4-5 times to obtain the acid-modified CNTs. The modified CNTs were then mixed with epoxy and stirred mechanically for 10 min. The mixture was heated at 120°C for 8 h to remove the vapors. The heated mixture was added with the nonionic surfactant and followed by the stirring for 30 min and sonication at 60°C for 30 min. The vacuum procedure was applied for 1 hr to remove the bubbles. The sonication and vacuum procedures were repeated for 2-3 times to obtain the mixture. The mixture was then poured into a mold, and hot-pressed at 120°C for 30 min to obtain the specimens. The surfaces of the specimens were fine-grounded to reduce the roughness effect on the mechanical properties.

Fig. 1 shows the shape and dimensions of the studied specimens. Three kinds of specimens with different CNT contents, i.e., 0, 0.5, and 1.0 wt.%, were employed in the experimental program to study the effect of CNT content on the tensile properties of the nanocomposites.

All static tensile tests were strain controlled at room temperature using an Instron 8872 servo-hydraulic material testing system associated with an extensometer. Three strain rates, i.e., 1.6×10^{-4}, 8.0×10^{-4}, and 1.6×10^{-3} 1/s were employed in the static tests to evaluate the strain rate effect on the mechanical properties of the studied nanocomposites.

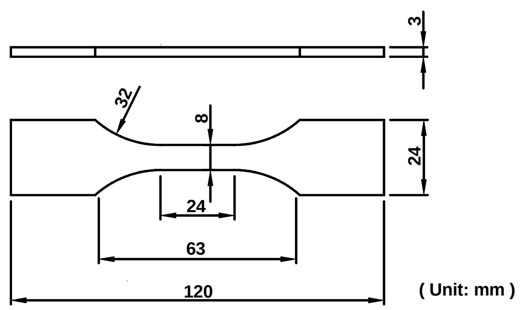

Fig. 1 Shape and dimensions of the studied specimen.

Results and Discussion

Fig. 2 and 3 show the experimental results of the tensile moduli and ultimate strengths of the studied MWCNT/epoxy composites tested under different strain rates, respectively. Fig. 2 shows that when the composites with the same CNT contents were tested under different strain rates, the obtained tensile moduli are almost identical. It indicates that the strain rate effect is slight on the tensile moduli of the studied CNT/epoxy composites.

Fig. 3 shows that for the composites with the same CNT contents, the corresponding ultimate strengths increase remarkably with the strain rates employed in the tensile tests. It demonstrates that the utilized strain rate in the tensile test affects significantly the ultimate strength of the studied composite. The increasing trend of the observed ultimate strengths for the composites becomes more obvious when more CNTs are embedded in the epoxy matrix.

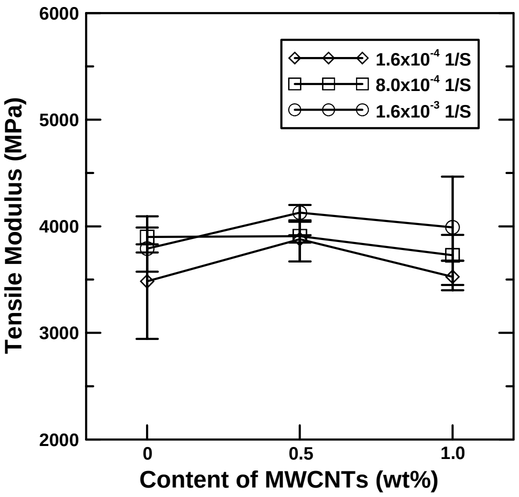

Fig. 2 Strain rate effect on the tensile moduli of the MWCNT/epoxy composites with various CNT contents.

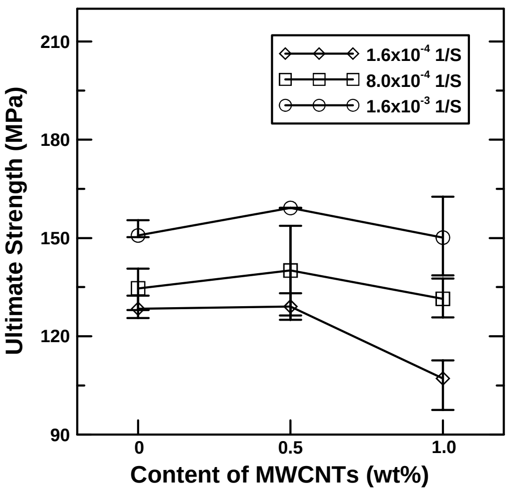

Fig. 3 Strain rate effect on the ultimate strengths of the MWCNT/epoxy composites with various CNT contents.

Figs. 2 and 3 also shows that the addition of 0.5 wt.% CNTs can increase the tensile modulus and ultimate strength of the epoxy material, indicating the high stiffness and modulus of CNTs significantly enhance the rigidity and strength of the composites. However, the tensile modulus and ultimate strength of the composite with 1.0 wt.% CNTs are lower than those with 0.5 wt.% CNTs. The plethoric CNTs result in the difficulties of dispersion, and the CNT agglomerations form the sites of stress concentrations, which are detrimental to the mechanical properties of the studied composites.

Conclusions

This research experimentally studies the strain rate effect on the tensile moduli and ultimate strengths of the MWCNT/epoxy composites with different CNT contents. The higher ultimate strength of the studied nanocomposite is observed when the higher strain rate is employed in the tensile test, while the strain rate has slight effect on the tensile modulus of the studied composite specimen. Furthermore, the experimental results show that the addition of 0.5 wt.% CNTs can effectively increase the tensile modulus and ultimate strength of the epoxy material. However, the studied nanocomposite with 1.0 wt.% CNTs presents lower modulus and strength than that with 0.5 wt.% CNTs. The stress concentrations resulted from the CNT agglomerations have adverse effects on the mechanical properties of the nanocomposites.

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