INTERLAMINAR SHEAR STRENGTH OF A NANOCOMPOSITE

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1. Introduction

Fibrous composites offer outstanding material properties and adaptability for use in the aerospace structures. With the discovery of carbon nanotubes, the prospect of enhancing existing mechanical and functional properties of composite materials has led to numerous efforts to understand the effects nanotubes would have on existing materials. An important material property associated with composite laminates is the interlaminar shear strength. Because the single wall carbon nanotubes theoretically have exceptional stiffness (>1 TPa) and tensile strength (100 - 600 GPa), it is proposed that adding them to the fiber-matrix interface of composite laminates could enhance material interlaminar shear strength properties.

A woven carbon fiber/epoxy composite laminate and single-wall carbon nanotubes (SWCNTs) are used in this study to assess the effects of SWCNTs on the interlaminar shear strength. The short beam shear test, described by the ASTM Standard D 2344/D 2344M, offers an easy and repeatable method for testing the apparent interlaminar shear strength of composite materials. In this study the apparent interlaminar shear strength at failure is calculated for a laminate specimen with and one without SWCNTs in the fiber – matrix interface in the midplane plies. Optical microscopy is used to assess the shear failure modes of the specimens

2. Materials, Specimen and Test Setup

Two (2) approximately 25 cm square pieces of woven $0^o/90^o$ carbon fabric were sprayed on both sides with a 0.05 wt% SWCNTs using an incipient spraying method developed by Barrera et al. [1]. The

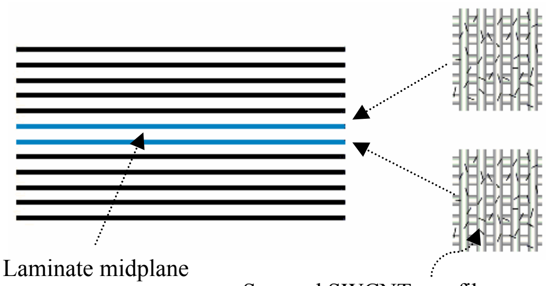

Fig. 1. Nanocomposite laminate cross-section

as received SWCNTs had been processed by the HIPCO method at CNI, Houston, TX, and then purified to less than 4% metal content. These pieces of sprayed woven fabric, shown in the Fig. 1 schematic, were placed at the midplane of a 12 ply fiber/matrix composite laminate fabricated by a vacuum assisted resin transfer molding (VARTM) method. A second 12 ply panel would not have any midplane woven fabric of the same type sprayed with SWCNTs and would serve as a baseline. The short beam specimens from the 2 panels were cut to physical dimensions approximately at Depth (d) = 4.6 mm, Length (L) = 28 mm, Width (b) = 9.3 mm. Tests were conducted according to ASTM D 2344/D 2344M standards (Fig. 2). Loading heads were placed at ℓ = 18.4 mm apart as in Fig. 2. Tests were run using the 444kN hydraulic testing frame. Load measurements were made using a Transducer Techniques 9kN load cell. Load **P** was applied at a rate of 0.5 mm/min at center span. The beam specimen is loaded until failure indicated by a drop in the applied load.

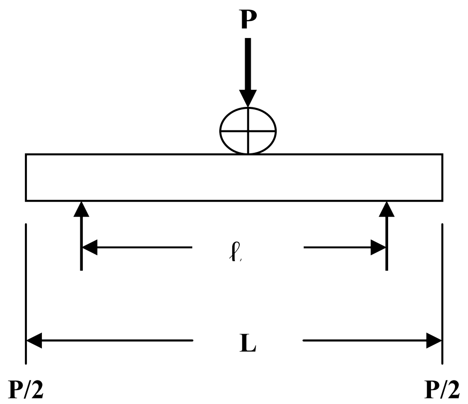

Fig. 2. Short beam shear test loading configuration

3. Analysis and Results

Five specimens from each panel were tested. Short beam shear strength was calculated using the formula,

$$S = 0.75P_m / (A),$$

where, S = short-beam strength; P_m = maximum load; A = specimen cross-section area (bxd). For the panel without nanotubes, the average short beam strength was 59.1 MPa with a standard deviation of 1.2 MPa and a coefficient of variation of 2.0%. This represents acceptable data correlation within the tests. For the panel with nanotubes at the midplane, the average short beam strength was 56.2 MPa, with a standard deviation of 0.9 MPa and a coefficient of variation of 1.7%, The difference in short beam shear strength between the two cases is an insignificant 0.8%. These results would suggest that the presence of SWCNTs have no affect on short beam shear strength of this nanocomposite laminate. However, through optical microscopy it is observed that the specimens with SWCNTs at the midplane failed not at the midplane of theoretical maximum shear load, but at ply interfaces above and the below the midplane (Fig. 3). The specimens without SWCNTs failed in shear at the midplane and at other location in the cross-section (Fig. 4).

4. Conclusions and Recommendations

The average short beam strength of the specimens with and without SWCNTs at the midplane was found to be of insignificant difference. However, a toughening effect of the SWCNTs was observed because the shear cracking shifted away from the midplane of the specimens in those cases where the SWCNTs were deposited.

Future work in this area will employ fracture toughness tests to obtain quantitative values for interlaminar shear toughness in modes I, II and mixed mode for these nanocomposite laminates.

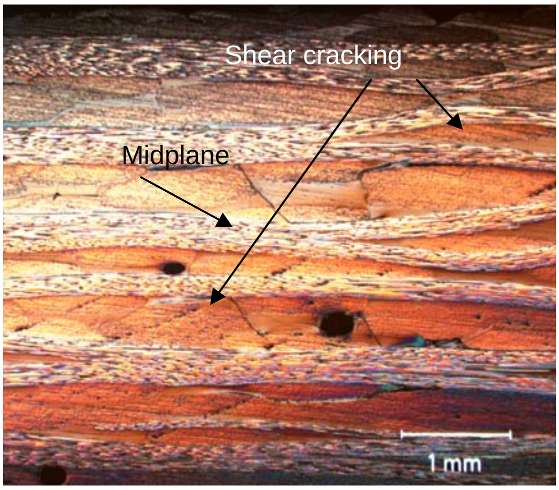

Fig. 3. Carbon fiber with SWCNTs

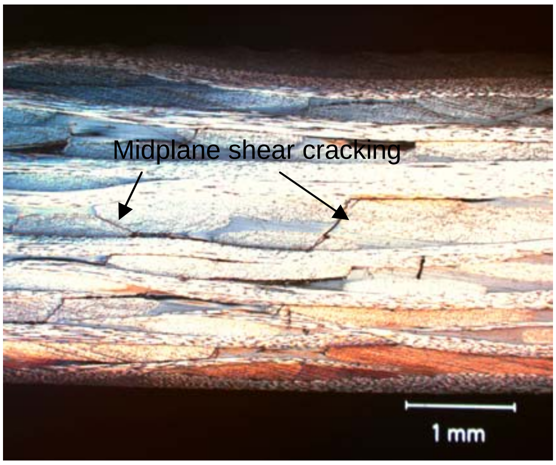

Fig. 4. Carbon fiber without SWCNTs

Acknowledgments

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References

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