탄소나노튜브 연결망을 이용한 복합재료 구조건전성 진단

Structural Health Monitoring of Composite Structures Using Percolated Carbon Nanotube Network

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1. Introduction

This paper presents a study on incorporation of carbon nanotubes (CNTs) in fiber-reinforced plastics for potential real-time structural health monitoring. CNTs dispersed in a solvent were uniformly spray-coated on the surfaces of glass fiber textile plies, which were then layed-up and impregnated with unsaturated polyester resin using vacuum-assisted resin transfer molding to form a 150 mm by 150 mm composite panel. Prior to resin infusion, electrodes were embedded on the periphery as well as between the plies for resistance monitoring. The composite panel was subjected to three-point bending, during which the changes in resistances between various electrode pairs were measured and recorded. Experimental results revealed the dependence of resistance change measurements on the loading conditions, amount of CNTs coated, measured directions, and presence of structural failure. The proof-of-concept was demonstrated by fabricating and testing with a miniaturized wind turbine blade.

2. Experimental

The thermal CVD-grown MWCNTs (CM-100) used in this study were provided by Hanwha Nanotech. DBLT-type glass fiber, which consists of stitched lamina of 0°, 90°, -45°, and 45°, was used as the reinforcement, and unsaturated polyester was used as the matrix.

In order to investigate the piezoresistive behavior of CNT-incorporated glass fiber composites, 150 mm X 150 mm composite panels were fabricated, as shown in Fig. 1. First, a weighed amount of MWCNT was dispersed in methanol, and the suspension was subsequently sprayed on glass fiber textile. Four plies of MWCNT-spray-coated glass fiber textile were layed-up, electrodes were embedded (8 electrodes per inter-layer; 24 electrodes total), and the resin was infused using vacuum-assisted resin transfer molding (VARTM).

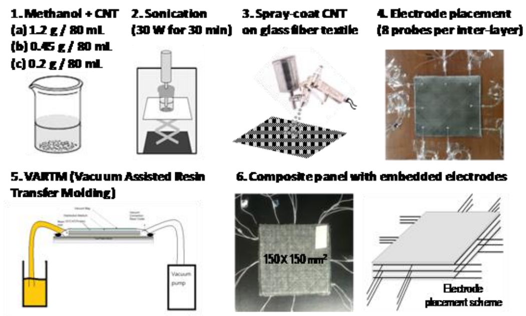


Fig. 1 Block diagram of multi-modal chatter model of a high speed machining center

The composite panel was subjected to three-point bending using a setup consisting of the Instron materials testing system, Keithley multimeter and switching device, and data acquisition and processing system (Fig. 2), and the applied load, deflection, and the change in resistance were measured *in situ*.

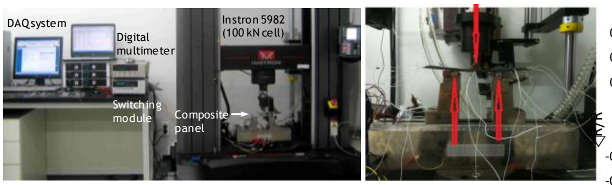
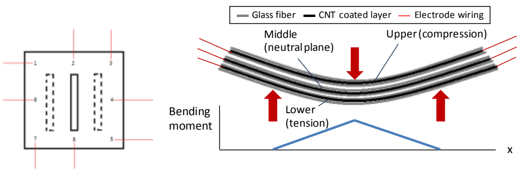


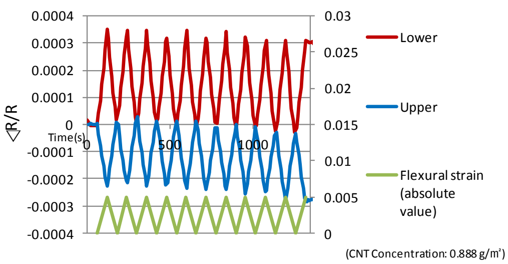
Fig. 2. Composite panel test setup

3. Results and Discussion

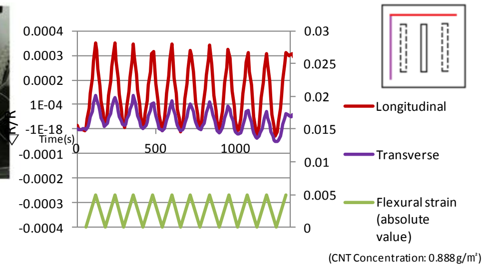
Figure 3 shows the piezoresistive response of the composite panels tested. Figure 3(a) shows the stress/strain states in the “upper,” “middle,” and “lower” inter-layers. Figure 3(b) shows an evident distinction between the upper interlayer, which is in compression, and the lower interlayer, which is in tension, as evidenced by the reversed signals. The middle inter-layer, which is neutral, shows negligible resistance change, as compared to the other inter-layers. Figure 3(c) shows the piezoresistivity difference between longitudinal and transverse directions. The change in longitudinal resistance is much greater than that in transverse resistance, as it is in alignment with the longitudinal strain direction.



(a) Composite panel configuration



(b) Tensile-compressive strain detection



(c) Longitudinal-transverse strain detection

Fig. 3. Piezoresistivity behavior of CNT-coated composite panels

4. Conclusions

1. Distributed CNT networks in glass fiber composites show positive resistance change to tensile strains, negative resistance change to compressive strains.
2. The density of CNT network seems to be inversely related to sensitivity, but warrants further investigation.
3. Multiple CNT layers and electrodes embedded in inter-layers enable composite failure mode prediction.
4. Proof-of-concept demonstration of structural health monitoring of composite panels paves the way for intelligent, real-time health monitoring of various composite structures, including aircrafts, civil structures, body armor, etc.

Acknowledgements

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