MECHANICAL PROPERTIES OF CARBON FABRIC-PHENOLIC RESIN COMPOSITE USING CARBON NANOTUBES

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Introduction

As offered several unique mechanical and thermal properties, carbon fiber-reinforced carbon matrix composites (C/C composites) have attracted much attention for their applications at elevated temperatures [1, 2]. The nose tips and wing edges of American spaceshuttles of Columbia, Discovery, and Challenger were manufactured by SiC coated 2D-C/C composites [3]. Also, C/C composites are broadly applied as brake discs in automobile industries and airplane [4]. For manufacturing C/C composites, phenolic resin was impregnated into the carbon fabric prepregs which was cured to polymer matrix composites (PMC). Then, the treatments of carbonization, graphitization, and densification were applied on the PMC to produce final C/C composites. However, there are few literatures for the investigations of the in-between polymer matrix composite which was carbon fiber-reinforced phenolic resin matrix composite. In this study, carbon nano-tubes were added into the composites for enhancing the properties. For this reason, the mechanical properties were evaluated. And the microstructures were examined by field-emission scanning electron microscopy (FE-SEM).

Experimental procedure

Materials
Thin multi-walled carbon nanotubes (Hanwha Nanotech, Korea) having a diameter of 15 nm were utilized as the nanoparticles. And plain woven carbon fabrics (Mitsubishi TR30, 3k) were cut into size of 20 cm × 20 cm for manufacturing composite.

Apparatus and Procedures
Three-roll mill method was applied in this study to disperse CNTs into phenolic resin. The gap width between the first and second rolls is set to 45, 30, 15, 5, and 0 μm, while the second gap is set to 15, 10, 5, 0, and 0 μm. Last two cycles are forcing milling. The adjacent rollers rotate at different speeds and opposite directions during the dispersing process. After that, resin films having thickness of 0.3 mm will be prepared by this homogeneous mixture. Then, B-staged resin films and carbon fabrics were laid-up one by one. Finally, the composites were manufactured by using a hot-pressing method.
The tensile test and three-point bending test were performed at room temperature and pressure using an Instron machine at Korean Institute of Materials Science (KIMS). The crosshead speeds for both tests were set at 0.5 mm/min. FE-SEM was utilized to observe microstructures of composites.

Results and Discussion

Tensile tests
After manufacturing carbon fabric-phenolic resin composite with 3 wt% CNTs reinforcements, tensile specimens were prepared. Five specimens were tested. The results of tensile strength were shown in Fig. 1

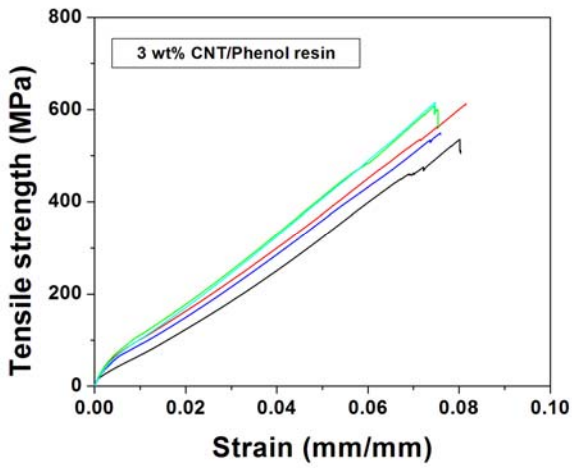

Fig. 1 Tensile strength of carbon fabric-phenolic resin composite reinforced by 3 wt% CNTs.

It is found that the composite reinforced by 3 wt% CNTs has a high tensile strength about 580 MPa.

Three-point bending tests
Furthermore, three-point bending tests were performed on five specimens.
The results of flexural stress were shown in Fig. 2. Moreover, the flexural stress, σ_f, is calculated by the following equation:

$$\sigma_f = \frac{3Pl}{2bd^2} \quad (1)$$

where P is the measured load, l is the span distance, b is breadth, and d is the height of the rectangular shape specimens.
As shown in Fig. 2, flexural stress was higher than about 320 MPa.

Microstructures

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Microstructure of tensile specimen was shown in Fig. 3. Matrix and carbon fiber were easy to be estimated. And CNTs were found in the phenolic resin matrix. Due to three-roll mill method was applied, agglomerate was not found. The debonding between carbon fiber and matrix was clearly presented in Fig. 3.

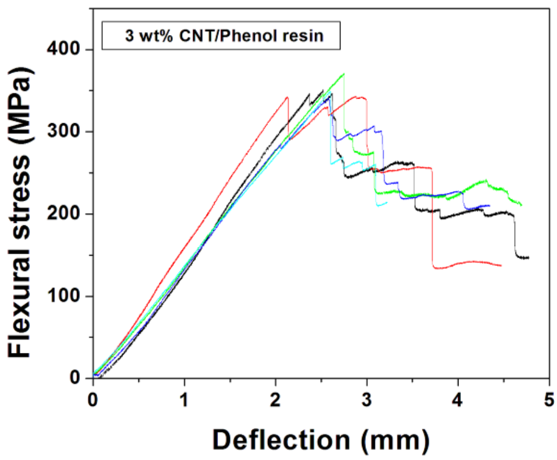

Fig. 2 Flexural stress of carbon fabric-phenolic resin composites reinforced by 3 wt% CNTs.

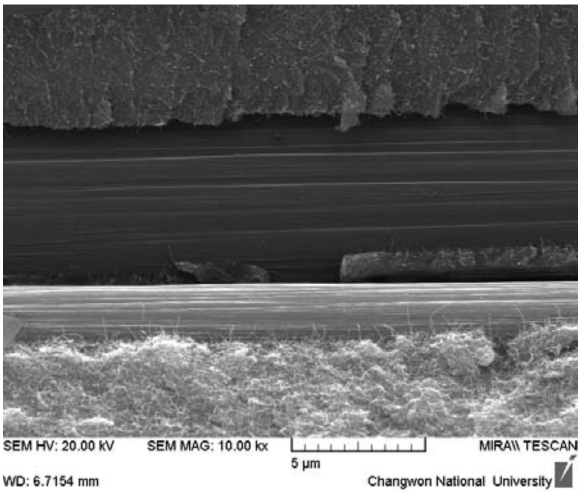

Fig. 3 SEM image of tensile specimen.

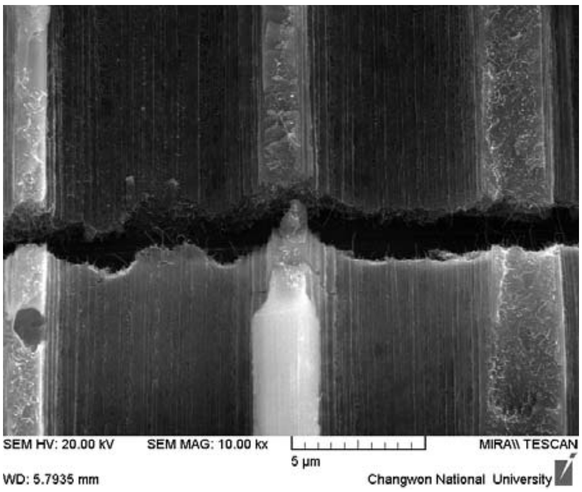

Fig. 4 SEM image of 3-p bending specimen.

Fig. 4 showed the SEM image of 3-p bending specimen. Carbon fiber could not be found in Fig. 4. However, from matrix, the surface of carbon fiber and the structure between two carbon fibers could be inferred. And the homogenous dispersion of CNTs in the matrix was proved. CNTs also could be observed at the fracture area. Although composite was failed at the crack shown in Fig. 4, bridging effect of CNTs was found that enhanced the mechanical properties of composite.

Conclusions

Carbon fabric-phenolic resin matrix composites reinforced by 3 wt% CNTs were manufactured and investigated in this study. The following results were summarized:

(1). The CNTs were well dispersed in the carbon fabric-phenolic resin composite.

(2). The composite reinforced 3 wt % CNTs has a tensile strength at about 580 MPa and the flexural stress at about 320 MPa.

(3). Debonding between carbon fiber and matrix was examined. Due to the well dispersion of CNTs, there was no agglomerate and bridging effect of CNTs might enhance the mechanical properties of composite.

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