THERMAL CONDUCTIVITY OF CARBON FIBER FABRIC/PHENOLIC RESIN COMPOSITES WITH CNT OR CNF ADDITION

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Introduction

The superior mechanical properties of carbon nanotubes (CNTs) and carbon nanofibers (CNFs) make them the ideal candidates for composite reinforcement. Although some experimental measurements indicated the enhancement of strength with the addition of CNTs into the polymer matrix [1-4], results without or with limited strength enhancement were also reported [3,4]. Two important issues concerning the applications of CNTs and CNFs in the composite reinforcement need to be overcome. The first is the uniform dispersion of these nano-reinforcing materials in the polymer matrix. The second is the effective stress transfer from the CNTs to the composite. For the effective stress transfer, the bonding between the reinforcement and the matrix should be strong, which make the surface properties of the CNTs and CNFs important.

Recently, incorporation of CNTs or CNFs in carbon fiber(CF)/polymer composites to form a hybrid multiscale composite was proposed and enhancements of mechanical behavior were reported [5-9]. However, few reports on the thermal conductivity of this type of composites were presented. In this study, both CNT and CNF were adopted to prepare the CNT or CNF/CF fabric/phenolic resin three-phase composites and the influences of CNTs and CNFs on the thermal conductivity and mechanical behavior of the composites were investigated.

Experimental

Fig. 1 shows the TEM images of CNTs and CNFs used in this study. The CNTs, 10-20 nm in diameter, have a tube structure (Fig. 1(a)) and the CNFs, produced in our laboratory (40-60 nm), have a structure with internal conical cavities (Fig. 1(b)). For the fabrication of CNT or CNF/CF fabric/phenolic resin composites, the CNTs or CNFs dispersed phenolic resin solution was prepared first with the aid of ultrasonication. Then the CF fabrics were impregnated with the solution and the vacuum bag hot pressing technique was used to fabricate the composites.

The mechanical properties and fracture behavior were studied using the three-point bending test according to ASTM D-790. The microstructure of the fracture surfaces of composites after bending tests was observed using FE-SEM. The thermal conductivity of CF fabric composites was measured in the thickness direction at room temperature by laser flash technique according to ASTM E1461 using an instrument of LFA 447 Nanoflash^{TM} (NETZSCH, Germany). The sample size was $8 \times 8 \times 1 \sim 1.2$ mm^3.

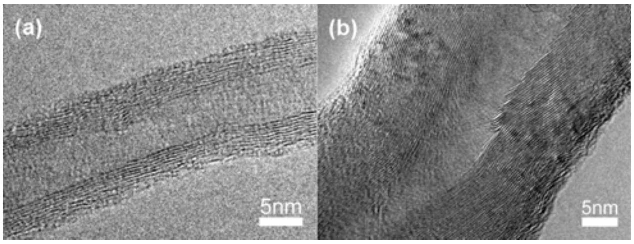

Fig. 1 TEM images of: (a) CNTs and (b) CNFs.

Results and Discussion

Fig. 2 shows the flexural strength of carbon fabrics reinforced phenolic resin composites with the addition of CNTs or CNFs at different amounts. The flexural strength was found to increase with increasing amount of CNT up to 0.5 wt%, where an increase of 24.4% was measured. However, a flexural strength even lower than that of the composites without CNT addition was obtained when the amount of CNT was over 0.5 wt%. Similar trend was also observed for the composites with the addition of CNFs. However, the maximum strength was lower than that of composites with CNT addition. The amount of CNF addition for the maximum strength was also lower (0.1 wt%) as compared with 0.5 wt% for the CNT addition. It has been shown [5,8,9] that the introduction of nano-reinforcement, for examples nanofibers and CNTs, in the laminated composites could lead to the enhancement of interlaminar shear strength and therefore, the strength of the composites.

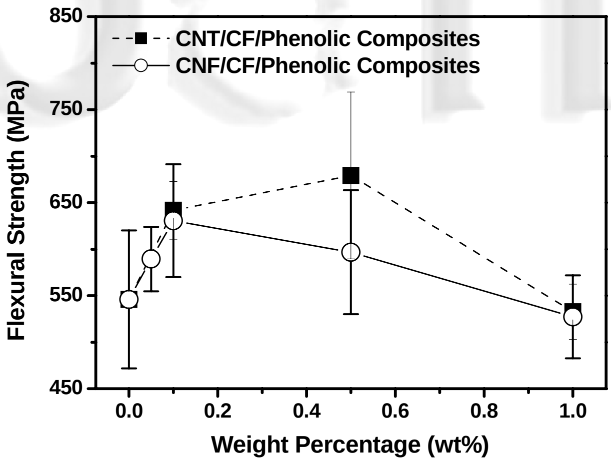

Fig. 2 Flexural strength of carbon fabrics reinforced phenolic resin composites with the addition of CNTs or CNFs at different amounts.

The thermal conductivity of carbon fabrics reinforced phenolic resin composites with the addition of CNTs or CNFs at different amounts was presented in Fig. 3. As shown in Fig.3, a best loading amount for the maximum thermal conductivity was also observed for both CNT and CNF. It is interesting to note that the best loading amounts for both CNF and CNT additions were the same as those for the flexural strength. However, as contrary to the strength results, in which CNT showed better reinforcement, better enhancement in thermal conductivity was observed for the CNF addition. Although the CNF showed better enhancement in thermal conductivity at the optimum loading, larger decrease in thermal conductivity was measured when the loading exceeded the optimum value (0.1%). On the contrary, relatively small variation in the thermal conductivity was found for the CNT addition within the loading range of 0.1~1.0 wt%. Also, the thermal conductivities measured in this study were all larger than that of the composites without CNT or CNF addition. However, the flexural strength could be lower than that of the composites without CNT or CNF addition when the addition was higher than the best amount.

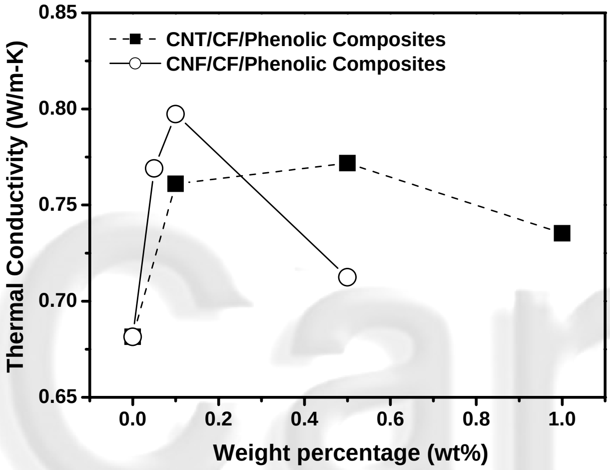

Fig. 3 Thermal conductivity of carbon fabrics reinforced phenolic resin composites with the addition of CNTs or CNFs at different amounts.

Conclusions

Introduction of CNTs or CNFs in the CF fabric/phenolic resin composites was found to increase the flexural strength and thermal conductivity of the composites. A best loading amount was observed for both CNT and CNF additions. Although the best loading amount was different for CNT and CNF additions, the best loading amounts for thermal conductivity were the same as those for the flexural strength. For the flexural strength, better reinforcement result was found with CNT loading. On the contrary, better enhancement in thermal conductivity was observed for the CNF addition.

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References

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