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Mechanical Properties and Creep Behavior of Carbon Fiber Nano-Composites

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Abstract. Recently, it has been observed that surface modification of carbon nanotubes（CNTs）influences on CNT's distribution among epoxy resin and affects the mechanical properties and electrical conductivities of CNTs. Owing to above-mentioned effects, carbon nanotubes treated with oxidizing in organic acids, a kind of surface modification, generates functional groups on the surface of CNTs taht is a major investigation in this study to enhance mechanical properties and electrical conductivities of CNTs. The influence of the different proportion contents of CNTs added into epoxy resin on mechanical properties and electrical conductivities of composites was investigated, and strength of material tested under different temperature environments was observed. Moreover, the creep behavior of carbon fiber（CF）/epoxy resin thermosetting composites tested under different temperature and stress were also concerned to be analyzed. The resulting creep behavior consists of only two stages, including primary creep and steady-state creep. The effects of creep stress, creep time, different humidity treatment on the various temperature creep of composites containing different proportion contents of CNTs were investigated.

It is believed that the increased creep strains can be attributed to higher applied stresses, longer creep times, higher humidity, higher temperature and lower hardnesses. The test results also exhibit that mechanical strength and electrical conductivity increase with the increase of CNTs content added into composites. In the influence of temperature effect on specimen, because of different coefficient of expansion among matrix, fiber and CNTs, the overexpansion of matrix caused by high temperature results in crack occurred among matrix. From observation of the fracture surface by SEM image, the debonding occurs and longitudinal fibers are pulled out due to poor interfacial bonding of fiber and matrix, which also results in entire strength degeneration.

Introduction

Incorporating nanoparticles or nanotubes into the matrix of fiber reinforced composites has been widely investigated in recent years [1]. and the elevated temperature creep deformation of engineering materials has received significant attention for many years [2,4]. Because of above-mentioned reason, surface modification of CNTs, mechanical strengths[5,6] and electrical conductivity of thermosetting composites with different proportion content (0.25, 0.5, 0.75 phr) of CNTs [7,8], and creep behavior of thermosetting composites tested under different circumstance with various temperatures, loads and humidities are considered to be major investigates in this study[9,10]. The results obtained by testing under different circumstances are adopted to investigate the mechanical strength, electrical conductivity and creep behavior.

Experimental

Materials and Experimental Procedure

MWCNT's employed as a reinforcement in this study were supplied from Desun mamo Co. , /Ltd. (diameter : 30-50 mm, length : 10-200mm, purity : 93%). Hot pressing was adopted for fabricating MWCNT's / epoxy resin prepreg laminate. Epoxy resin acts as matrix and the pressure at l000 psi, temperature at 150℃ are requirements for epoxy to shape up. In experimental procedure, MWCNTs were dispersed among isopropyl alcohol, and stirred it with Titanium (IV) n-butoxide, (3-aminopropyl) triethoxysilane (APTES) and HCl for 48 hours, and then placed it in a heating oven to bake it for modifying CNTs. The mixed solution with great distribution CNTs was poured into liquid impregnation sink first, then the fixed size carbon fiber prepreg was placed into solution. Ultrasonication method was adopted for distributing the solution with CNTs among carbon fiber prepreg well. After completing impregnation, the carbon fiber prepreg was placed into a heating oven to remove residual solution by baking under the temperature at 50℃ for 6 hours to produce the CNTs / epoxy resin prepreg. After that, the prepregs were piled up into the mold, and hot pressing must be done under pressure at 1000 psi, temperature at 150℃ for 30 min. for fabricating the prepreg laminates.

Measurement

Tensile strength , flexural strength , impact strength , electrical conductivity and hygroscopicity test were performed in this study according to the standards of ASTM D3039, ASTM D790, ASTM D256, ASTM D257 and ASTM D570-98 respectively. Furthermore, the variation of flexure strength of composites with different CNT content tested under three different temperatures at 25 ℃ ,85 ℃ and 175 ℃ also be investigated. Moverover, creep strain tested under different circumstance including different temperatures, humidities and stresses were also carried out and investigated finally.

Results and discussion

Static strength test

Figures 1 (a) and (b) show the comparison on mechanical strength between unmodified CNT-added composite and modified CNT-added composite. According to the test results, the mechanical strength of modified CNT-added composite is higher than that of unmodified CNT-added composite.

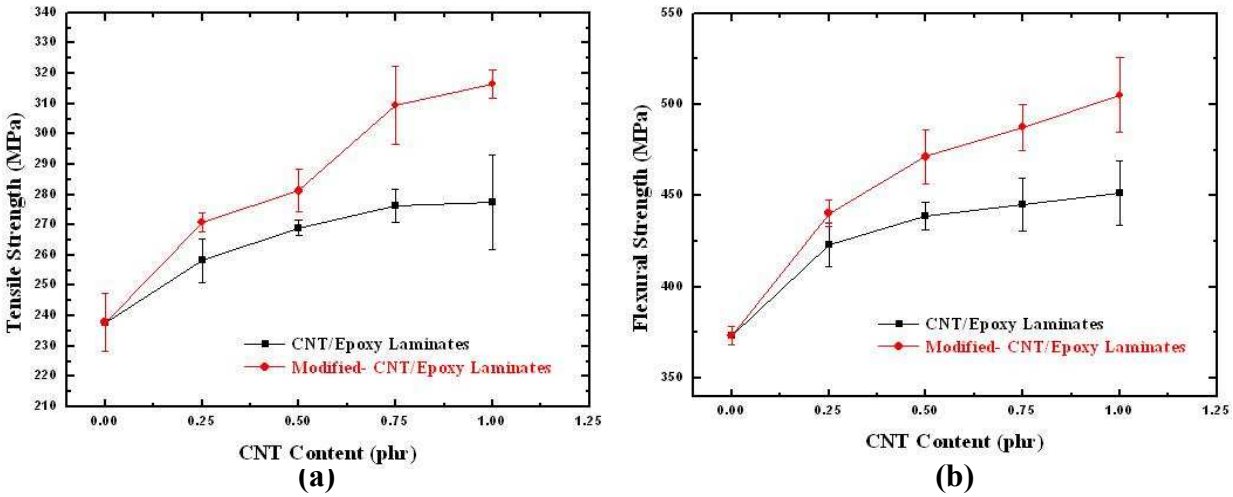
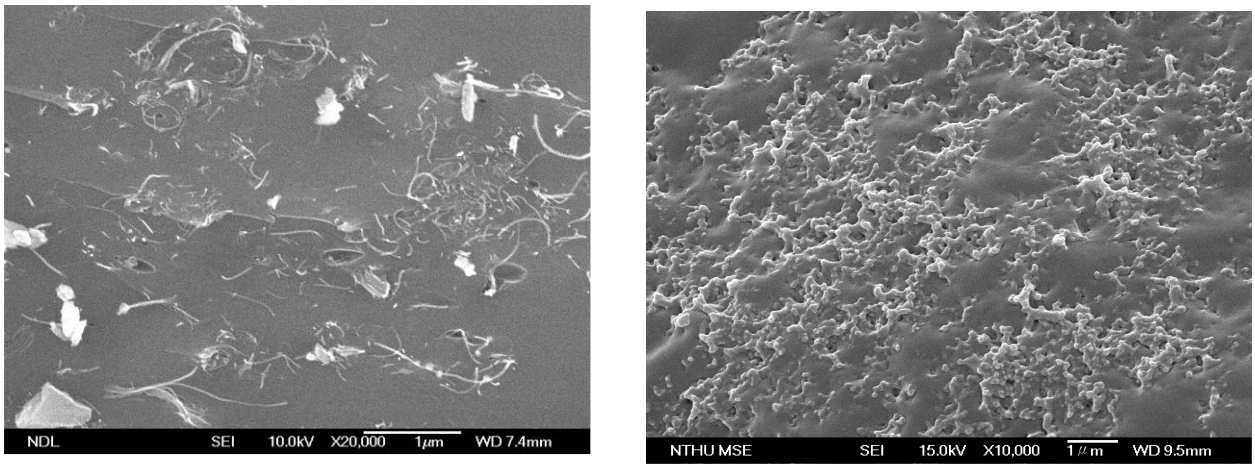


Figure 1. (a) Tensile strengths of modified-CNTs and unmodified-CNTs composites. (b) Flexure strengths of modified-CNTs and unmodified-CNTs composites

Figures 2 (a) and (b) depict the distribution situation of unmodified CNTs and modified CNTs among epoxy resin prepreg laminate observed through SEM image. From Fig. 2 (a), the

agglomeration occurs around local area and distribution of CNTs among epoxy resin is poor than that of modified CNTs among epoxy resin shown in Fig. 2 (b).



(a) **(b)**

Figure 2. (a). Dispersion of unmodified CNTs among the epoxy resin atrix. (b). Dispersion of modified CNTs among the epoxy resin matrix

Hence, modified CNT-added composite possesses great mechanical strength. According to the mechanical test results, the strength increase with increasing CNTs content. This result indicates that adding content of CNTs plays a crucial role of reinforcement for nanocomposite.

Electrical Conductivity

Surface resistivities obtained are shown in figure 3. The CNTs/epoxy resin prepreg laminates possess better electrical conductivity than that of the pure epoxy resin prepreg laminates.

On the basis of previous resion, the electrical conductivity of CNTs/epoxy resin prepreg laminate increase with the increase of CNTs content, and moreover the electrical conductivity of modified-CNTs/ epoxy resin prepreg laminate is higher than that of unmodified-CNTs/epoxy resin prepreg laminate.

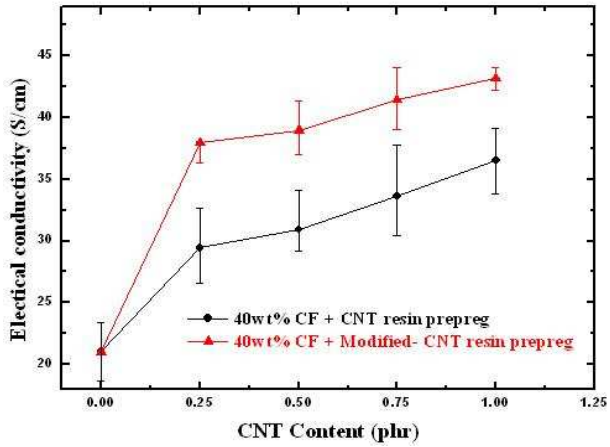
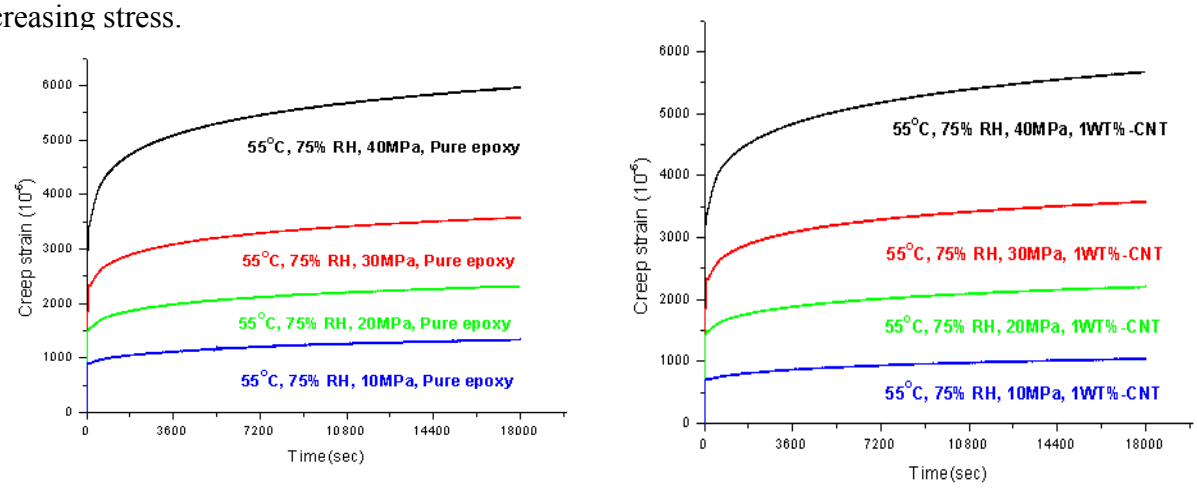


Figure 3. Electrical conductivities of modified-CNTs and unmodified-CNTs/CF/epoxy resin laminates

Creep Behavior

As shown in figures 4 (a) and (b), the creep behavior of CF/epoxy resin and CNTs/ CF/epoxy resin thermosetting composite were performed at a constant temperature of 55℃, a constant relative humidity (75%RH) and four different loadings. The creep strain of composites increases with increasing stress.

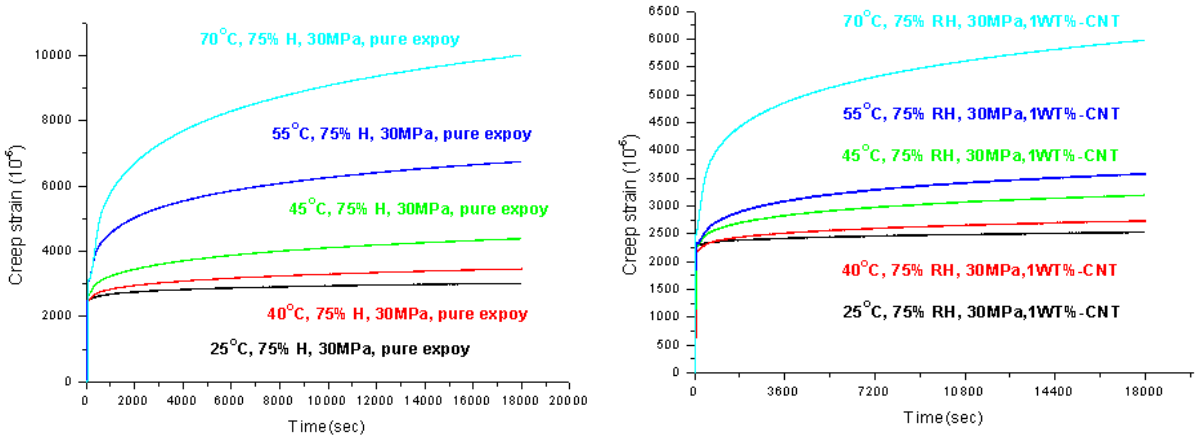


(a) **(b)**

Figure 4. (a) Creep behavior of CF/epoxy resin laminates tested under constant temperature, relative humidity and four different loadings. (b) Creep behavior of CNTs/CF/epoxy resin laminates tested under constant temperature, relative humidity and four different loadings

Figures 5(a) and (b) show the creep behavior of CF/epoxy and CNTs/CF/epoxy resin composite performed under a constant loading of 30MPa, constant relative humidity of 75%H and five different temperatures （25℃,40℃,45℃,55℃,70℃）, respectively.

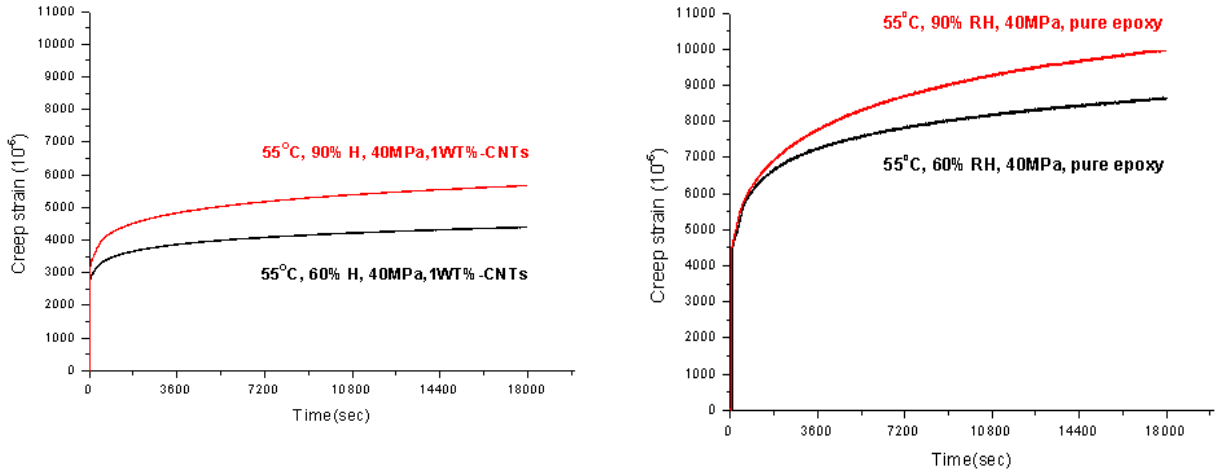
The creep strain of composites increases with the increase of temperature. Especially, creep behavior occurs notably while specimen is tested at the high temperature of 70℃.



(a) **(b)**

Figure 5. (a) Creep behavior of CF/epoxy resin laminates tested under constant loading, relevant and five different temperatures. (b) Creep behavior of CNTs/CF/epoxy resin laminates tested under constant relative humidity, constant loading and five different temperatures.

Figure 6 (a) shows the creep behavior of CNTs/CF/epoxy resin composite performed under a constant loading, a constant temperature and two different relative humidities. Fig. 6 (b) depicts the creep behavior of CF/epoxy resin composite performed under a constant loading, a constant temperature and two different relative moistures.



(a) **(b)**

Figure 6 (a) Creep behavior of CNTs/CF/epoxy resin laminates tested under a constant loading of 40MPa, a constant temperature at 55℃and two different relative moistures（60%RH, 90%RH）. (b) Creep behavior of CF/epoxy resin laminates tested under a constant loading of 40MPa, a constant temperature at 55℃and two different relative moistures（60%RH, 90%RH）.

Figure 7 depicts that the creep strain of CNTs/CF/epoxy resin composite decreases with increasing amount of CNTs. According to previous results, CNT can be regarded as a major reinforcement on mechanical improvement. For this property, adding proper amount of CNTs also can retard creep strain rate.

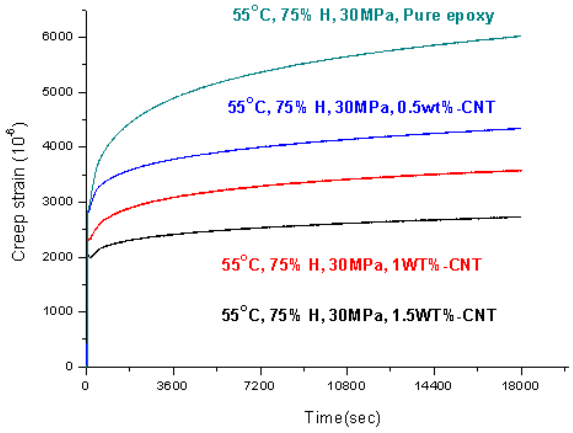


Figure 7. Creep behaviors of CF/epoxy resin thermosetting composite and CNTs/CF/epoxy resin composites containing various proportions of CNTs tested under a constant temperature, relative humidity and loading.

Conclusions

According to the test results, the mechanical strength of modified CNT-added composite is higher than that of CNT-added composite because the distribution of modified CNTs among epoxy resin is better and great interfacial bonding between modified CNTs and epoxy resin without any agglomeration status. Hence, modified CNT-added composite possesses great mechanical strength. Because of the great electrical conductivity of CNTs, the electrical conductivity of CNT-added composite is better than that of the pure resin laminate. Therefore, the electrical conductivity of CNT-added composite apparently increases with increasing CNTs content. From the test results and comparisons of creep behavior between CF/epoxy and CNT/CF/epoxy resin laminates tested under various circumstances, loading, temperature and humidity can be regarded as the crucial factors to

influence on the creep behavior. According to previous results , CNT can be regarded as a major reinforcement on mechanical improvement, for this property, adding proper amount of CNTs also can retard creep strain rate.

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