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Nanocharacterization of creep behavior of multiwall carbon nanotubes/epoxy nanocomposite

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ABSTRACT

High temperature instrumented indentation testing was used to evaluate the mechanical properties of multiwall carbon nanotubes/epoxy nanocomposite system. Reference neat epoxy samples were also tested and compared with the results obtained for the nanocomposite. The nanoindentation creep tests were utilized to provide the creep strain rate sensitivity parameter, the contact creep compliance and the time-dependent deformation under constant loads. Different thermo-mechanical conditions comprising three temperatures of 25, 40 and 55 °C and three loads of 1, 2 and 3 mN were utilized. The improvements in the properties were not as high as anticipated through the use of mixture rule, indicating insufficient dispersion. However, variations in modulus, hardness and creep strain rate sensitivity parameter obtained using nanoindentation showed quantifiable differences between the MWCNTs nanocomposite and epoxy specimens.

The comparison of the creep strain rate sensitivity $A/d(0)$ from short term, 60 s, creep tests and the creep compliance $J(t)$ from the long term, 1800 s, creep tests suggests that former parameter is a more useful comparative creep parameter than the creep compliance. The analysis of the creep strain rate sensitivity clearly revealed that the addition of MWCNTs to a commercial epoxy reduced the creep rate. This reduction of creep rate sensitivity parameter was observed particularly at thermal environments just below the glass transition temperature.

1. Introduction

The fabrication of high performance nanotube-based composites is driven by the ability to create anisotropy at the molecular level in order to obtain optimal mechanical properties. The structural strength and toughness of polymers could be significantly increased using carbon nanotubes. For example, a cast composite film consisting of polystyrene and carbon nanotubes (5% volume fraction) exhibits a 100% increase in the modulus and 25% increase in the strength of the polystyrene (Thostenson and Chou, 2002).

The investigation of the mechanical behavior of polymeric composites based on CNTs is a topic of ongoing research. Several investigations have studied the elasticity (Li et al., 2008; Selmi et al., 2007), damage (Kao and Young, 2010), buckling (Bower et al., 1999; Li and Wei, 2006), tribology (Giraldo et al., 2009; Wang et al., 2008) and toughness (Sun et al., 2009) of CNTs based composites. Other groups have investigated the changes in the glass transition behavior of polymers as a result of adding carbon nanotubes (Gong et al., 2000; Shaffer and Windle, 1999).

Recently, the viscoelastic and creep behavior of CNTs based composites gained momentum toward using them for damping applications. Zhou et al. (2004), have utilized uniaxial tensile test to measure the loss factor of nanocomposites based on SWCNTs. Alternatively, Suher et al. (2005) utilized direct viscoelastic shear mode of CNTs–epoxy composite thin films to

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