Interfacial sliding-driven hysteresis in polymer/carbon nanotube nanocomposites

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Abstract

High-performance, lightweight polymers integrated with carbon-based nanofillers, such as carbon nanotubes (CNT), stand out as structural nanocomposites with enhanced stiffness, strength, toughness and damping capacity. In the last decade, nanocomposite materials drew significant attention fostered by the high tunability of their nonlinear constitutive behavior [1]. The nanocomposites mechanical and damping response can be tailored and optimized by directly modifying their microstructural and CNT/matrix interfacial features. The embedding of CNTs in different polymer hosting matrices may have different effects, such as modifying the natural assembling of polymer chains and causing changes in the elastic properties of the polymer. CNTs dispersion, distribution and orientation affect homogeneity, uniformity and anisotropy of the nanocomposite. In addition, a rich variety of CNT/matrix interfacial interactions may be achieved (also exploiting chemical and physical functionalizations), thus enabling several interfacial mechanisms. Strong adhesion at the CNT/matrix interfaces ensures the load transfer and interlocking mechanisms while, for weaker CNT/matrix interfaces, the dissipative stick-slip or debonding can occur.

An extensive experimental campaign is carried out to observe hysteresis arising in nanocomposites. Different thermoplastic polymers are selected as hosing matrix, i.e. polypropylene (PP), polycarbonate (PC), polybutylene terephthalate (PBT), and combined with low and high aspect ratio nanotubes. Cyclic tensile and bending tests are performed by applying a constant strain rate and increasing strain amplitudes. In commodity polymer nanocomposites, considerable hysteresis is already observed at very low strain amplitudes and it is mainly due to the viscoelastic behavior of the polymers. On the other hand, in engineering polymer nanocomposites, the material response is initially purely elastic (at low strain levels). Increasing the cyclic strain amplitudes, hysteresis arises due to a dissipative interfacial frictional sliding mechanism between the nanotubes and the polymer chain surrounding them [2]. Such stick-slip behavior, is the main source of energy dissipation in engineering nanocomposites. The onset of stick-slip energy dissipation is regulated by the nature of the CNT/matrix interaction forces, through the interfacial shear strength. On the other hand, the magnitude of the energy dissipation due to stick-slip is controlled by the amount of interfacial surface area available for the slippage of the polymer chains around the CNTs. Therefore, CNTs with higher aspect ratio provide higher damping capacity and larger hysteresis loops. Morphology and geometry of the CNTs are identified as key parameters that regulates the nonlinear constitutive behavior of the nanocomposite [3] together with the interfacial shear stress and the polymer microstructural properties. This work provides insights into the inner relationships between the microstructural features and the macroscopic response of CNT/polymer composites, thus introducing morphological parameters to detail and enrich the constitutive formulation for such nanostructured materials. Leveraging on the

tunability of the CNT nanocomposite mechanical and damping properties, a tool to design desirable hysteresis trends in high-performance multifunctional nanocomposites is given.

References

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