Reinforcement of Inorganic Nanotubes/Elastomer Composites. Theory versus Experiment

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Abstract

Reinforcement of polymers by strong fibrous network permits fabrication of Polymer Composites characterized by high tensile strength, high stiffness, high fracture toughness, good abrasion resistance; good puncture resistance; good corrosion resistance, low cost etc. We present experimental and theoretical analyses of mechanical properties of polyurea elastomer nanocomposite based on inorganic MoS2 nanotubes. The addition of a small amount of nanotubes leads to an increase in the Young’s modulus of up to 40%. The Young’s modulus is measured within the temperature range from 80 °C to 280 °C and frequencies 0.05-40Hz. We compare the experimental data with theoretical modeling. The modeling is based on currently available effective medium approximations [1-6].

1. Composites

Combine different materials with the objective of getting a more desirable combination of properties. For instance to get the flexibility and light weight of a polymer plus the strength of a ceramic. Matrix is a continuous phase which transfers a stress to other phase(s). Dispersed phase enhances matrix properties. Properties of Composites are determined by: Properties of the fibers; Orientation of the fibers; Concentration (volume fraction) of the fibers; Fiber – matrix bonding; Properties of the matrix.

4. Composite Strength (2)

Discontinuous fibers model (valid at $L_t > 15/d$) where $L_t$ – fiber length, $d$ – fiber diameter, $\tau$ - shear strength of fiber-matrix interface

Elastic modulus in fiber direction

$$E_{eff} = E_{mf} + E_f K_V$$

$K$ is the efficiency factor:

- aligned 1D: $K = 1$ (aligned parallel)
- aligned 2D: $K = 0$ (aligned perpendicular)
- random 2D: $K = 3/8$ (2D isotropy)
- random 3D: $K = 1/5$ (3D isotropy)

7. Nielsen's modification of Halpin - Tsai

$$P = P_0 \left(1 + \frac{1}{1 - \frac{f}{f_0}}\right)$$

$P$ is the packing fraction where $P_0$ is the maximal packing fraction $P_0^{ref}=0.785$ for fibers arranged in a square array $f_0=9.065$ for fibers arranged in a hexagonal array $f_0=0.82$ for fibers randomly distributed with a close packing

Halpin – Tsai works better than “rule of mixtures” in a whole temperature region

References


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