APLICATION OF THE HYBRID BOUNDARY NODE METHOD TO HEAT CONDUCTION ANALYSIS OF CNT COMPOSITES

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Carbon nanotubes (CNT) are predicted to possess superior heat conductivity and considerably improve heat conducting properties of polymers. In this work, the equivalent heat conductivities of CNT-based nanocomposites with curved CNTs are evaluated. A 3-D nano-scale representative volume element (RVE) model is used and, as a solution technique, the hybrid boundary node method (HBNM) employed. Both the temperature distribution and heat flux concentration are studied. The equivalent heat conductivity of the RVE as a function of the nanotube curvature is calculated and discussed in detail. It is found that, unlike the mechanical properties, the nanotube curvature has no significant influence on the equivalent heat conductivity of the composites.

Keywords: Carbon Nanotube, Meshless Method, Nanocomposite, Heat Conductivity, Hybrid Boundary Node Method

1. Introduction

Over the last decade, carbon nanotubes have been attracting considerable attentions both from scientists and engineers. Intensive research has been carried out on carbon nanotubes for their production, physical properties and possible applications [1]. The carbon nanotubes are predicted to possess exceptional physical properties such as superior heat and electrical conductivities, as well as high stiffness and strength. A few recent experiments have been reported on mats of compressed ropes of CNTs [2], from which values of thermal conductivity of CNTs ranging from 1750 to 5850 W/m·K have been extrapolated. The direct measurements of individual nanotube were also tried with the MEMS assisted new measurement technology [3]. Following those experiments, several preliminary molecular dynamics simulations of the thermal conductivity gave even higher values, namely 6600 W/mK at 300 K [4]. Although the estimated values of thermal conductivity were different from each other, it is generally accepted that the CNTs possess excellent heat conductivity comparable or even better than diamond, considered so far as the best heat conductor.

These remarkable properties of CNTs may make them ideal for a wide variety of technological applications. One of the most intriguing applications is the use of CNTs as a small volume fraction filler in nanotube-reinforced polymers. CNT-based composites offer significant improvements in performance over their base polymers. It has been demonstrated that with only 1% (by weight) of CNTs added in a matrix material, the stiffness of a resulting composite can increase between 36% and 42% and the tensile strength by 25% [5].

CNTs are different in sizes and forms when they are dispersed in a matrix to make a nanocomposite. They can be single-walled or multi-walled with length of a few nanometers to a few micrometers, and can be straight, twisted and curled, or in the form of ropes. Their distribution and orientation in the matrix can be uniform and unidirectional or random. All these factors may substantially influence the equivalent properties of the nanocomposites.

A critical issue that has yet to be examined is the impact of the shape of the embedded nanotube on the effective properties of the nanotube-reinforced polymer. Using the FEM, Fisher et al. [6] analyzed the effects of the nanotube waviness on the modulus of the nanocomposite through a RVE with a curved nanotube. They found that the nanotube curvature significantly reduces the effective reinforcement when compared to straight nanotubes.

In this paper, we focus on thermal property of the CNT-based composites. We also use a representative unit volume with a curved nanotube embedded to assess the impact of nanotube waviness on the equivalent heat conductivity of the nanocomposites.

The implementation of standard numerical solution techniques like FEM or BEM may face severe difficulties in discretization of the domain geometry under consideration. This is valid especially for FEM models where meshing of the solid geometries within CNT-reinforced polymers may be (and usually is) tedious and extremely difficult. To alleviate this difficulty the hybrid boundary node method (HBNM) can be used [7-8]. By combining a modified functional with the moving least squares (MLS)