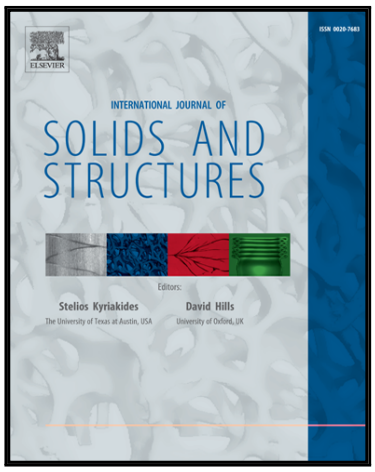

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Out-of-plane bending of carbon nanotube films

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Abstract: Carbon nanotube (CNT) films are easily bent in their applications because the dimension in thickness is much smaller than the other two dimensions. Therefore, it is of great importance to understand the bending mechanisms and to predict the bending stiffness of CNT films. In this paper, the out-of-plane bending stiffness of CNT films is studied based on energy analysis and validated by finite element simulations. It is found that the pure bending of CNT films consists of two types of deformation, i.e. the out-of-plane deformation and the in-plane deformation, which both contribute to the bending stiffness. Moreover, the bending stiffness threshold of CNT films, i.e. the critical CNT concentration to judge whether or not the film can bear bending load, is revealed. This threshold is different from the in-plane stiffness threshold but equivalent to the electrical percolation threshold because the inter-tube interactions can only transfer out-of-plane moment. The bending stiffness threshold as well as the two in-plane stiffness thresholds divide the bending stiffness behavior of CNT films into four stages, which is described by a simple piecewise analytical expression based on the energy theorems and superposition method. Besides, this study shows that the CNT curliness and inter-tube connection saturation can influence the bending stiffness by affecting the thresholds. The method and results of this study can be extended to other networks constructed by nanotubes and/or nanowires as well.

Keywords: out-of-plane load, bending stiffness, stiffness threshold, carbon nanotube networks, buckypaper.