CONTINUUM MODELLING OF NANOBEAMS

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Abstract: Nanoscale beams are commonly found in nanomechanical and nanoelectromechanical systems (NEMS) and other nanoscale devices. Bending tests are also used for characterization of materials at the nanoscale. Surface energy has a significant effect on nanoscale structures, and it is associated with their size-dependent behaviour. This study is also motivated by recent experiments on large deflections of chromium cantilevers and modelling based on the classical large deflection beam theory to simulate experiments. A new large deflection beam model that accounts for surface energy is presented. It is shown that the model is capable of simulating experiments by using size-independent properties such as bulk elastic modulus and surface residual stress. The model is then used to explain the softening or stiffening behaviour observed experimentally in nanocantilevers and relative size-independency of clamped-clamped beams. Size-dependency of elastic modulus (or stiffening/softening) is a modelling artefact introduced due to the use of classical elasticity theory for nanostructures, and the current model shows that simulations based on classical beam theory requires careful interpretation. The model can be specialized for small deflections to obtain a set of closed-form analytical solutions for static response of thin and thick beams under different loading (point and uniformly distributed) and boundary conditions (simply-supported, cantilevered and clamped ends), and the solution of free vibration characteristics of such beams. An intrinsic length-scale for beams is identified that depends on the surface properties and cross-sectional shape.