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A Higher-Order Nonlocal Elasticity and Strain Gradient Theory and Its Applications in Wave Propagation

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Abstract

In recent years there have been many papers that considered the effects of material length scales in the study of mechanics of solids at micro and/or nano-scales. There are a number of approaches and, among them, one set of papers deals with Eringen's differential nonlocal model and another deals with the strain gradient theories. The modified couple stress theory, which also accounts for a material length scale, is a form of a strain gradient theory. The large body of literature that has come into existence in the last several years has created significant confusion among researchers about the length scales that these various theories contain. The present paper has the objective of establishing the fact that the length scales present in nonlocal elasticity and strain gradient theory describe two entirely different physical characteristics of materials and structures at nanoscale. By using two principle kernel functions, the paper further presents a theory with application examples which relates the classical nonlocal elasticity and strain gradient theory and it results in a higher-order nonlocal strain gradient theory. In this theory, a higher-order nonlocal strain gradient elasticity system which considers higher-order stress gradients and strain gradient nonlocality is proposed. It is based on the nonlocal effects of the strain field and first gradient strain field. This theory intends to generalize the classical nonlocal elasticity theory by introducing a higher-order strain tensor with nonlocality into the stored energy function. The theory is distinctive because the classical nonlocal stress theory does not include nonlocality of higher-order stresses while the common strain gradient theory only considers local higher-order strain gradients without nonlocal effects in a global sense. By establishing the constitutive relation within the thermodynamic framework, the governing equations of equilibrium and all boundary conditions are derived via the variational approach. Two additional kinds of

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