A Continuum Model with Microstructures for Wave Propagation in Ultra Thin Films

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Abstract

Ultrasonic waves are powerful and popular methods for measuring mechanical properties of solids even at nano scales. The extraction of material constants from the measured wave data requires the use of a model that can accurately describe the wave motion in the solid. The objective of this paper is to develop a continuum theory with microstructures that can capture the effect of the microstructure or nanostructure in ultra-thin films when waves of short wavelengths are used. This continuum theory is developed from assumed displacement fields for micro/nano-structures. Local kinematic variables are introduced to express these local displacements and are subjected to internal continuity conditions. The atomistic crystal structure of the thin film, for the sake of simplicity, is represented by a lattice model. The dimensions of the crystal structure naturally appear in the constitutive equations and the equations of motion of the representative continuum. The accuracy of the present model is evaluated by comparing dispersions of free harmonic waves predicted by the continuum model and exact analysis based on the lattice model. Specifically, dispersion curves for surface wave propagation and wave propagation in a thin film supported by an elastic homogeneous substrate are studied. The inadequacy of the conventional continuum theory is discussed.