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Acoustoelasticity of Polycrystalline Materials; a Formalism based on the Self-Consistent Elastic Constants

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Elastic constants of polycrystalline materials can be obtained through methods of ensemble averages of the elastic constants belonging to individual grains. Assumptions are often made to relate the local strains (stresses) within individual grains as a result of a macroscopic strain (stress) on the polycrystal. The different assumptions lead to different estimates for the elastic constants of polycrystals. However, an exact formulation is possible, which enforces continuity (at the grain boundaries) between the macroscopic strain (stress) and the strain (stress) in the grain. The resulting estimates of the polycrystal's elastic constants are known as self-consistent because either a stress or strain formalism leads to the same estimates.

This presentation extends the idea of macroscopic and local continuity of stress and strain and applies it to the theory of acoustoelasticity. Acoustoelasticity describes the dependence of the properties of an elastic wave on the stress state in the material supporting the wave. The self-consistent formalism enters the elastic constitutive relation developed by C.-S. Man and co-workers. Such a constitutive relation is a function of initial stress, which can be either residual stress resulting from a series of inhomogeneous plastic deformations or generated from external mechanisms. The constitutive relation is used to derive the stress-dependent Christoffel equations for the polycrystal. Solutions to the Christoffel equation yield expressions for the phase velocities and displacement directions of elastic waves in a stressed polycrystal. A comparison is made between phase velocity values based on ensemble averaging originating from the self-consistent formalism and the phase velocities arriving from previous models. The cases in which the present model shows considerable differences from the previous models are presented. This overall goal of this work is to provide a better understanding of the influence of polycrystalline microstructure on acoustoelasticity.

References:

1. C.-S. Man and R. Paroni, "Two micromechanical models in acoustoelasticity: a comparative study," J. Elast. **59** (1), 145-173 (2000).