Ultrasound Scatter in Heterogeneous 3D Microstructures

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This paper reports on a computational study of ultrasound propagation in heterogeneous metal microstructures. Random spatial fluctuations in elastic properties over a range of length scales relative to ultrasound wavelength can give rise to scatter-induced attenuation, backscatter noise, and phase front aberration. It is of interest to quantify the dependence of these phenomena on the microstructure parameters, for the purpose of quantifying deleterious consequences on flaw detectability, and for the purpose of material characterization. Valuable tools for estimation of microstructure parameters (e.g. grain size) through analysis of ultrasound backscatter have been developed based on approximate weak-scattering models. While useful, it is understood that these tools display inherent inaccuracy when multiple scattering phenomena significantly contribute to the measurement. It is the goal of this work to supplement weak scattering model predictions with corrections derived through application of an exact computational scattering model to explicitly prescribed microstructures. The scattering problem is formulated as a volume integral equation (VIE) displaying a convolutional Green-function-derived kernel. The VIE is solved iteratively employing FFT-based convolution. Realizations of random microstructures are specified on the micron scale using statistical property descriptions (e.g. grain size and orientation distributions), which are then spatially filtered to provide rigorously equivalent scattering media on a length scale relevant to ultrasound propagation. Scattering responses from ensembles of media representations are averaged to obtain mean and variance of quantities such as attenuation and backscatter noise levels, as a function of microstructure descriptors. The computational approach and GPU implementation will be summarized, and examples of application will be presented.

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