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Numerical Investigation of Ultrasonic Scattering Phenomena at the Grain-Scale in Polycrystalline Materials

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In polycrystalline materials, elastic waves strongly interact with grain boundaries and their propagation generates complex ultrasonic scattering phenomena. The recorded signals are generally difficult to interpret but contain rich information useful for characterizing the polycrystalline microstructure. Mastering the correlation between the ultrasonic grain scattering and the crystallographic and morphological characteristics of the microstructure is therefore essential. It is now widely recognized that grain-scale finite element (FE) modeling enables us to properly investigate grain-scale scattering mechanisms by fully grasping the multiple scattering phenomena. It allows to simulate synthetic microstructures and to analyze the influence of specific grain arrangements on the wave scattering. It is also a way to investigate the response of real microstructures, obtained, for instance, from EBSD maps and for which no explicit analytical model is available.

This contribution presents recent modeling and simulation results obtained using a space discontinuous Galerkin (dG) FE solver. First, the advantages of the space dG method and aspects for an appropriate numerical setting in the context of ultrasound scattering modeling are discussed. Second, the coherent wavefronts are analyzed by means of the attenuation coefficient, allowing the quantification of average microstructural characteristics. Among these, the grain-size distribution is mainly investigated here. For example, a recent method proposed for identifying bimodal grain-size distributions in 2D microstructures is extended to the 3D case, and the dimensionality of the grain scattering phenomena is discussed. Third, the structural noise due to incoherent waves is studied in 2D and 3D. The scattering coefficient is evaluated numerically and compared to analytical models. Some numerical “experiments” are carried out to discuss, confirm or refute theoretical hypotheses.