Abstract

The thesis focuses on application of ultrasonic guided waves (GW) to detect microstructural defects in polycrystalline materials. The goal of the thesis is to identify microstructural defects at inception using high-frequency excitation. A comprehensive understanding of the interaction of GW with polycrystalline microstructure is therefore essential. Here, first, the computational microstructure is generated using Voronoi tessellation. The required microstructural morphologies are obtained from an Electron Backscatter Diffraction (EBSD) test conducted on an actual polycrystalline specimen. A novel technique using the domain decomposition method is adopted to reduce the computational cost of generating Voronoi tessellation with a large number of grains. Next, the microstructure is imported to the finite element (FE) platform, ANSYS-APDL, and anisotropic material properties are assigned. FE simulations are performed in different frequency regimes for 2-D and 3-D polycrystalline microstructures with different average grain sizes. Here, the GW is generated by localized excitation and results are compared thoroughly with the conventional bulk ultrasonic wave. Dedicated in-house experiments are conducted to validate the numerical results of GW. The scattering of GW is thoroughly studied by analyzing amplitude attenuation and phase velocities. The new results associated with locally excited GW such as increased magnitude of scattering-based attenuation and decreased power of frequency dependency were observed. These features of GW are more convincing for defect/flaw detection than those of bulk wave because they demonstrated greater sensitivity to scattering events. Additionally, distinct features such as simultaneous propagation of P and S waves observed with locally excited GW help in a comprehensive understanding of microstructure, supplying additional information associated with S waves. This shows that GW is a better candidate for understanding the scattering event. Later, the interaction of GW with microstructures of different grain size distributions is studied. Finally, a 1-D Convolutional Neural Network (CNN) model is developed to predict grain size distribution in polycrystalline materials solely from their ultrasonic wave responses. This work aims to advance the in-situ characterization of microstructures using GW and enhance the early detection of microstructural defects to prevent potential catastrophic failures.

Keywords: NDE, Voronoi tessellation, Guided wave, 1D-CNN, Microstructure characterization, Attenuation, Scattering, Phase velocity.