Elastic Wave Propagation and Heat Diffusion Studies in Polycrystalline Material

S Shivaprasad[1], S. Unnikrishnakurup[1], K. Balasubramaniam[1], C. V. Krishnamurthy[1]

[1] Indian Institute of Technology Madras, Chennai, Tamil Nadu, India

Abstract

Introduction
The heterogeneous nature of materials at a certain scale has a significant impact on the macroscopic behavior of multi-phase materials. The physics and mechanics of the underlying microstructure are responsible for the various phenomena occurring in the macroscopic level. The overall behavior of micro-heterogeneous materials depends strongly on the size, shape, spatial distribution and properties of the microstructural constituents and their respective interfaces [1]. For instance, ultrasonic testing of materials is affected by microstructural parameters like grain size and texture. When a beam of ultrasound propagates through a polycrystalline material, acoustic energy gets scattered at grain interfaces due to the difference in acoustic impedances between different grains. This scattering results in loss of acoustic energy from the beam, resulting in energy attenuation. Loss in energy can significantly affect the ability to detect defects while performing experiments[2]. It is hence necessary to have a better understanding of effects of elastic/thermal anisotropy, grain size and grain-size distribution on elastic wave propagation and heat diffusion mechanism respectively.

Use of COMSOL MULTIPHYSICS ®
Here, we use Livelink™ for MATLAB® for implementing the finite element simulation for elastic wave propagation and heat diffusion studies on polycrystalline material. Llyod's algorithm is used for generating two dimensional controlled Voronoi polygons. Each polygons or cells are then assigned random grain orientations for defining effective elastic/thermal conductivity values. Internal cell interfaces are assigned displacement continuity for wave propagation studies, whereas three different boundary conditions: heat continuity, thermally thin resistive layer (TTRL) and a highly conductive layer (HCL) were considered for heat diffusion problem. The entire modelling flowchart is shown in Figure 1.Averaged values of displacement and temperature components were extracted from specific nodal points over the entire iteration.

Results
The role of cell size distributions, effects of average cell size on scattering of long and short wavelength elastic waves, and influence of orientational averaging on elastic wave propagation and heat diffusion for materials with various anisotropy ratios will be discussed.

Conclusion
A 2D Voronoi cell tessellation model is proposed for representing randomly oriented

anisotropic single crystal grains in polycrystalline material for elastic wave propagation and heat diffusion studies. Results indicate the possibility of representing an anisotropic polycrystalline material by an effective medium under certain conditions.

Reference

[1] Benedetti, I., and M. H. Aliabadi. "A three-dimensional grain boundary formulation for microstructural modeling of polycrystalline materials."Computational Materials Science,67, 249-260 (2013).

[2] Ghoshal, Goutam, and Joseph Turner. "Numerical model of longitudinal wave scattering in polycrystals." Ultrasonics, Ferroelectrics, and Frequency Control, IEEE Transactions on 56, no. 7,1419-1428(2009).

Figures used in the abstract

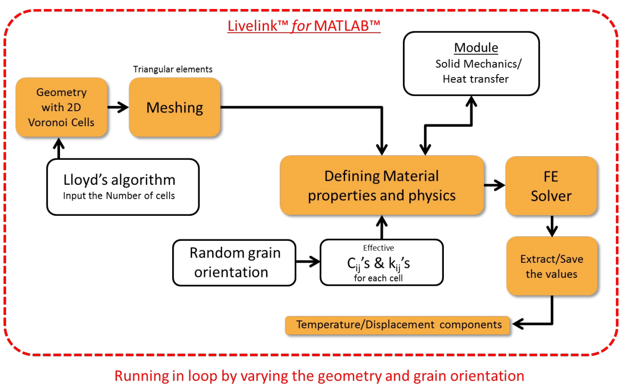

Figure 1: Flowchart of the Simulation Process.