Simulative Evaluation of Intragrain Precipitate Influence on the Material Nonlinearity using Nonlinear Ultrasound

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Nondestructive evaluation using ultrasonic waves is commonly used to experimentally probe for the presence of defects (i.e. dislocations, precipitates, cracks) in complex metallic microstructures. Such defects and abnormalities are evidenced by monitoring the acoustic nonlinearity parameter $\beta$. However, from the mathematical standpoint, the correlation between the microstructural behavior and the measured acoustic nonlinearity parameter is not explicit yet. The present work aims to assess the existence of statistical correlations between microstructural defects and material nonlinearity. The effects of defect geometry, density, and geometrical arrangements (i.e. relative position) on material nonlinearity are studied. To do so, the acoustic response of Fe-Cu single crystals containing 1 % Cu precipitates with radii on the order of 10 nm is simulated by means of finite element analysis. Several thousand initial microstructures with random arrangement of precipitates are virtually tested using statistical methods, such as principal component analysis. Therefore, it is expected that a causal link can be made between the acoustic nonlinearity parameter and the precipitates-induced microstructural behavior via the proposed numerical analysis.