Acoustoelasticity in Materials: The Influence of Plastic Deformation on Wave Propagation

Marcel Ruetz*[1], Thomas Antretter†[2], and Hans-Peter Gänser‡[1]

[1]Materials Center Leoben Forschung GmbH – Austria

[2]Institute of Mechanics, Montanuniversität Leoben, Franz Josef-Straße 18, 8700 Leoben, Austria. – Austria

Abstract

Ultrasonic waves are widely used in non-destructive material testing, from defect detection to residual stress analysis. A critical factor influencing wave propagation is the material's microstructure, especially dislocation density changes resulting from plastic deformation. This study extends the acoustoelastic theory by Hughes and Kelly to formulate a model that connects plastic strain with changes in acoustoelastic constants based on metal physics. The theoretical model describes the relationship between dislocation density and propagation velocity, predicting that plastic deformation decreases velocity quadratically. By integrating established theories such as the generalised Taylor rule and the Kocks-Mecking model, a connection is established between dislocation density or the plastic strain and acoustoelastic constants. The theoretical model describes the relationship between dislocation density or plastic strain and propagation velocity. To validate these predictions, experimental measurements from literature are compared, with the theoretical predictions demonstrating a strong alignment. These findings provide a reliable quantitative tool for assessing plastic strain and offer valuable insights to advance ultrasonic testing with respect to residual stresses and plastic strain in plastically deformed materials.

*Speaker

†Corresponding author: thomas.antretter@unileoben.ac.at

‡Corresponding author: hans-peter.gaenser@mcl.at