**Thermo-acoustoelastic Characterization of Plates using Zero Group Velocity Lamb Waves**

**Niket Pathak1, Rosa E. Morales2, David M. Stobbe2, and Todd W. Murray1**

1University of Colorado Boulder

Boulder, CO 80309

2Lawrence Livermore National Laboratory

Livermore, CA 94550

ABSTRACT

There is strong interest in the development of techniques to quantify applied or residual stress in parts, and to characterize material nonlinearity through measurement of higher order elastic constants. Residual stresses, for example, are often introduced into a part during fabrication or in subsequent material forming processes where the part is exposed to spatially varying temperature distributions. These residual stresses can have a negative effect on part performance, fatigue resistance, and dimensional stability. Ultrasound is one of the leading nondestructive techniques to detect stress and elastic nonlinearity through the acoustoelastic effect, a characteristic of material anharmonicity that gives rise to a link between ultrasonic velocity and stress.

Recently, we demonstrated that the change in velocity of certain Lamb wave resonances could be used to characterize the nonlinear elastic properties of plates through measurement of the third order elastic constants1. More specifically, zero group velocity (ZGV) Lamb wave resonances were excited and detected optically in 6061-T6 aluminum plates under uniaxial loading, and the changes in the resonance frequencies were compared to those predicted using acoustoelastic Lamb wave theory. Here, we investigate the effects of temperature change and stress on ZGV resonances in metal plates. We develop a thermo-acoustoelastic model for Lamb wave propagation that considers both thermal strain associated with temperature change and mechanical strain induced by external loading. The model is used to predict the effects of temperature and stress on ZGV resonances, and the results indicate that, in general, ZGV resonance are quite sensitive to small temperature changes. Furthermore, the shifts in ZGV resonances with temperature can be used to extract information about the higher order elastic constants that can, for example, supplement measurements taken under mechanical strain. The theory is validated using several samples including thin plates of several aluminum and steel alloys, pure aluminum, copper, and tungsten.

**Keywords:** ultrasonic testing, acoustoelastic effect, third order elastic constants, zero group velocity modes, thermos-acoustoelastic effect

REFERENCES

(1) R.E. Morales, N. Pathak, J.S. Lum, C.M. Kube, T.W. Murray, and D.M. Stobbe, Acoustoelastic characterization of plates using zero group velocity Lamb modes, Appl. Phys. Lett. 124, 084101 (2024).