**Sources of Uncertainty in Ultrasonic Phase-Based Assessment of Interfacial Stiffness in Adhesive Joints**

Webster, M., Spaeth, P., Hudson, T.

Quantitative nondestructive evaluation (NDE) of adhesive joint strength is critical for certifying fastener-free bonded aerospace structures. Unfortunately, available adhesive NDE approaches are only suitable for detecting gross defects and delamination and cannot reliably detect variations in strength in intact bonds.

Intact (i.e., nominally defect free) bonds are challenging to inspect because they, by definition, contain no macroscopic defects that would produce a strong NDE signature. Even in the absence of obvious defects, however, bond strength can vary substantially due to factors such as contamination, variations in the adhesive cure processes, and environmental exposure. For ultrasonic bond inspections, the effect of interactions from an imperfect adhesive interface are subtle and may include changes in the frequency content or phase of the ultrasonic signal. The bond condition can be deduced from these subtle changes in the acoustic response using an accompanying physics-based model of adhesive joint interaction. For example, researchers have used the spring network adhesion model of Baik and Thompson [1] to determine the interfacial stiffness of the joint from its ultrasonic response [2]. This interfacial stiffness metric describes the resistance to separation between the adhesive and adherent and has shown a strong correlation with joint strength.

In this study, interfacial stiffness is assessed using the ultrasonic phase change associated with bond interaction in varying bond conditions. The phase change is measured precisely using a phase-locked-loop instrument over a swept range of frequencies. The phase transition at resonance, where the bond thickness is half the acoustic wavelength, produces a unique signature with which to fit a physics-based model. Interfacial stiffness is determined by minimizing the difference between the theoretical and experimental phase response. Experimental results are presented for glass specimens bonded with aerospace adhesives and a sensitivity analysis is performed to examine the effects of parameters that may be uncertain in the industrial inspection environment – namely bond thickness, adhesive and adherent properties, and porosity. The results are a first step toward an uncertainty quantified version of the measurement technique, show correlation between interfacial stiffness and bond strength, and are another key step toward maturing this approach for use in complex materials and joint geometries.

[1] Baik, J.M. and Thompson, R.B., 1984. “Ultrasonic scattering from imperfect interfaces: a quasi-static model”. Journal of Nondestructive Evaluation, 4.

[2] Haldren, H.A., Perey, D.F., Yost, W.T., Cramer, K.E., and Gupta, M.C., 2019. “Swept-frequency ultrasonic phase evaluation of adhesive bonding in tri-layer structures”. Journal of the Acoustical Society of America, 145.