Model-Based Software for Simulating Ultrasonic Pulse/Echo Inspections of Metal Components

C.-P. Thomas Chiou, Frank J. Margetan, Daniel J. Barnard, Ronald A. Roberts, Matthew R. McKillip and Jared L. Taylor; Center for Nondestructive Evaluation, Iowa State University, 1915 Scholl Road, Ames, IA 50011-3042

The use of models to simulate inspections has played a key role in UT NDE R&D efforts. Over the years, a series of wave propagation models, flaw response models, and microstructural backscatter models have been developed at CNDE to address inspection problems of interest. One use of the combined models is the estimation of signal-to-noise ratios (S/N) in circumstances where backscattered echoes from the microstructure (grain noise) act to mask sonic echoes from internal defects. Such S/N models have been used to address questions of inspection reliability, such as how to optimize the choices of transducer properties and inspection design to insure that critical defects are reliably detected. Under the sponsorship of the National Science Foundation's Industry/University Cooperative Research Center at ISU, an effort was initiated in 2015 to repackage existing research-grade software into user friendly tools for the rapid estimation of S/N for ultrasonic inspections of metals.

This presentation provides an overview of the ongoing modeling effort, with emphasis on recent developments. The software can now treat both normal and oblique-incidence immersion inspections of curved metal components having equiaxed microstructures in which the grain size varies with depth. Both longitudinal and shear-wave inspections are treated. The model transducer can either be planar, spherically-focused, or bi-cylindrically-focused. A calibration (or reference) signal is required, and is used to deduce the measurement system efficiency function. This can be “invented” by the software using center frequency and bandwidth information specified by the user, or, alternatively, a measured calibration signal can be used. Defect types include flat-bottomed-hole (FBH) reference reflectors, and spherical pores and inclusions. Simulation outputs include estimated defect signal amplitudes, RMS grain noise amplitudes, and S/N ratios as functions of the depth of the defect within the metal component. At any particular depth, the user can view a simulated A-scan displaying the superimposed defect and grain-noise waveforms. The realistic grain noise signals used in the A-scans are generated from a set of measured “universal” noise signals whose strengths and spectral characteristics are altered to match predicted noise characteristics for the simulation at hand. Examples are presented comparing measured and predicted A-scan signals for FBHs in Nickel-alloy components. We also discuss efforts currently underway to generate a simulated C-scans (including grain noise speckle) corresponding to inspections in which the model transducer is scanned above the defect. As will be demonstrated as part of this poster presentation, the software typically requires only a few seconds to complete a simulation when running on a typical laptop computer.