Application of Seismic Unix to Nondestructive Imaging

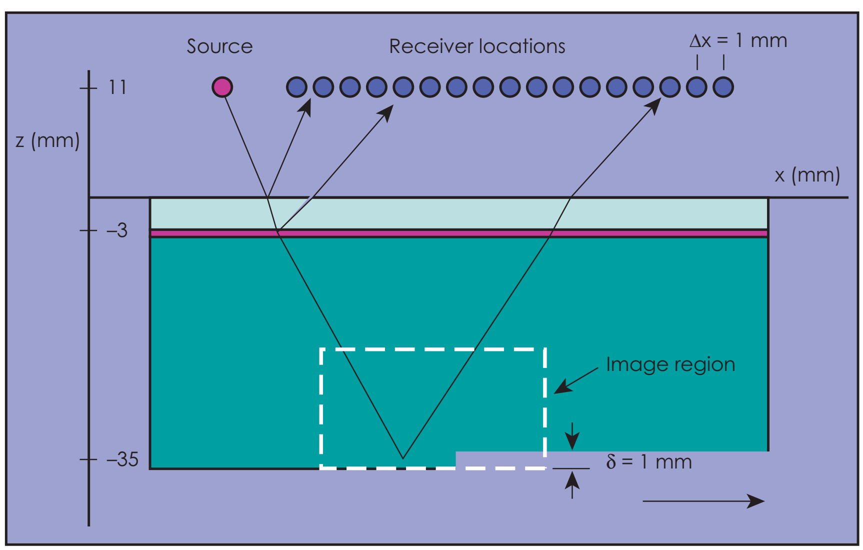
We have applied existing seismic imaging codes and algorithms to characterize high-contrast multilayered planar structures at ultrasonic frequencies. These newly obtained competencies provide unique tools and leverage a wealth of prior knowledge from the seismic-geophysical scientific community. Realizing this technology has significantly enhanced LLNL's imaging and characterization capabilities, typically encountered with stockpile and recertification programs.

Project Goals

Our project goal was to assess the utility and applicability of state-of-the-art seismic imaging software to typical programmatic ultrasonic NDE problems. To evaluate the utility of these algorithms, we produced a simple planar test part containing multiple elastic layers with large acoustic impedance mismatches. With this simple test case we generated several numerical and experimental sets of data that were then used as input to the seismic reconstruction codes.

Relevance to LLNL Mission

The motivation for this project was to directly support long-range plans to enhance LLNL's core technologies relating to imaging and characterization. In doing so, we have generated a knowledge base, applicable to a variety of multilayered high-contrast elastic structures. These new competencies are directly applicable to numerous LLNL programs such as ADAPT, and the stockpile recertification initiatives.



Water	Tantalum	Acrylic	Sylastic
C_L = 1.5 mm/μs	C_L = 4.1 mm/μs	C_L = 2.5 mm/μs	C_L = 1.21 mm/μs
C_t = 1.5 mm/μs	C_t = 1.1 mm/μs	C_t = 1.3 mm/μs	C_t = 0.9 mm/μs
ρ = 1.0 gm/cm^3	ρ = 16.6 gm/cm^3	ρ = 1.1 gm/cm^3	ρ = 0.9 gm/cm^3

Figure 1. Geometry for the 2-D planar multilayered part. The lower acrylic boundary has a uniform step change of 1.0 mm. For each material, the longitudinal and shear wave speeds are listed along with the density. The dashed square is the imaging region shown in Figs. 3 and 4.

For more information contact
Karl A. Fisher
(925) 423-0132
fisher34@llnl.gov

FY2005 Accomplishments and Results

A planar test case was used to generate numerical and experimental data sets for the Stanford University Seismic Unix reconstruction package. The computational geometry and the corresponding source receiver locations relative to a multilayered planar elastic structure are shown in Fig. 1. The materials of the structure were specifically chosen to have large acoustic impedance mismatches between layers. This requirement was driven by the need to maintain relevant similarities to programmatic components and to test the robustness of the seismic migration algorithms.

We performed a series of numerical experiments on the multilayered planar part to simulate an ultrasonic scan. Elastic wave propagation was modeled using E3D, a finite-difference time-domain code. Numerical data sets were then created in a full multi-static process whereby multiple sources sequentially ensonified the part with a broadband pulse centered at 2.25 MHz. The corresponding scattered field was then recorded at each receiver location. The resulting numerical data was then input into the Seismic Unix application for image generation.

Figure 2 depicts how the experimental data were collected. A single linear scan along the upper surface of the part is generated by holding the source fixed while the receiver is moved relative to the source. The reflected acoustic signals are recorded at each receiver location as a function of time; this generates what is known in the seismic community as a "normal move out."

Numerical and experimental data were then input into the Seismic Unix processing environment.

Reconstructions of the numerical data for the multilayered planar part are shown in Fig. 3. The step feature is clearly visible with adequate localization of acoustic energy. Further effort could be expended to reduce the ripples and multiple echoes, but for a proof-of-concept analysis, this is sufficient.

Experimental results are illustrated in Fig. 4. Here the goal was to accurately locate the lower boundary of the acrylic layer using these seismic techniques.

In this study we have successfully shown that seismic approaches can be applied to ultrasonic NDE problems.

Related Reference

Fisher K. A., S. K. Lehman, and D. H. Chambers, "Development of a Multi-View Time Domain Imaging Algorithm with a Fermat Correction," *J. Acoust. Soc. Am.*, **118**, 5, pp. 1115-1136, 2005.

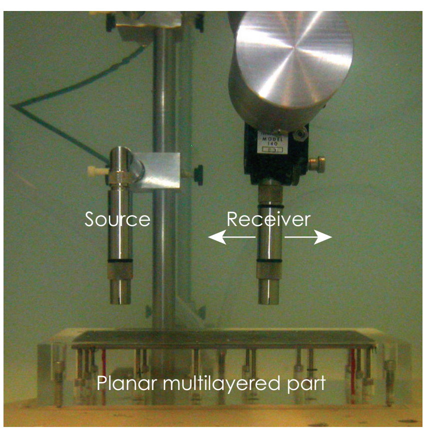


Figure 2. Photograph of the experimental scan geometry in the immersion tank. The source, a 2.25-MHz transducer, is held fixed relative to the upper surface of the planar multilayered part. The receiver is another 2.25-MHz transducer that is mechanically scanned along the axis of the part. The planar test part was constructed using the dimensions and materials properties shown in Fig. 1.

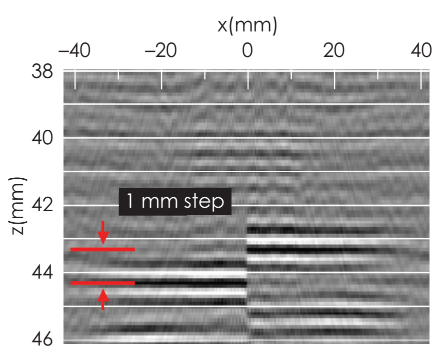


Figure 3. Numerical reconstruction of the lower acrylic boundary in the region near the planar step (dashed white box in Fig. 1). Several convolution filters in conjunction with the basic migration operation have clearly outlined the 1-mm step feature in the correct location. The boundaries are well defined with a minimum of pulse-induced artifacts.

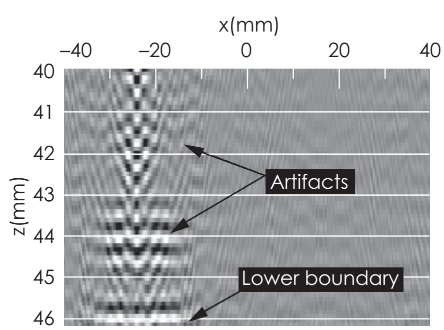


Figure 4. Experimental reconstruction of the lower acrylic boundary. The reduced quality of this reconstruction is a result of having only one source location. This limited data set introduces several artifacts in the image, resulting in a series of "phantoms" above the lower boundary. Multiple views would eliminate these artifacts. Reflection energy from the lower boundary is concentrated and accurately located.