Localization and Characterization of Fatigue Cracks Around Fastener Holes Using Spherically Focused Ultrasonic Probes

Deborah Hopkins¹, Marvin Datuin¹, John Aldrin², Mark Warchol³, Lyudmila Warchol³, David Forsyth³, Charlie Buynak⁴ and Eric Lindgren⁴, ¹Berclie Corp., Berkeley, CA 94703, ²Computa-
tional Tools, Gurnee, IL 60031, ³TRI/Austin, Austin, TX 78746 and ⁴Air Force Research Labor-
atory (AFRL/RXCA), Wright-Patterson AFB, OH 45433

Results are presented from laboratory experiments and simulations designed to determine the ability to localize and characterize fatigue cracks around fastener holes using spherically fo-
cused ultrasonic (UT) probes for shear-wave inspections. In designing and evaluating inspection protocols, the number of cases that can be studied through laboratory experiments is severely
limited by cost and time constraints. Simulations therefore stand to play a significant role in the design and optimization of inspection strategies for those conditions that can be accurately mod-
eled. Moving from benchmark studies for relatively simple geometries toward more realistic conditions creates significant challenges. For shear-wave inspections of fastener holes these
challenges include the complex energy field in the thin plates, reflections off the borehole, the complexity of making measurements in the near-field, material anisotropy, cracks as small as
1mm square, and a sealant layer between aluminum sheets. To achieve comparable modeling and simulation data requires a very accurate experimental setup that allows the probe angle,
probe height and scan path to be precisely set. For the modeling, care must be taken to match the applied gain and gates used during acquisition of the experimental data. Initial results presented
include sensitivity studies to determine how probe variables (frequency, focal depth, diameter), crack variables (size, shape, location, angle with respect to the probe), and the experimental
setup affect results. Simulated and experimental C-scan images for 5 and 10 MHz probes are
shown in Figure 1 for a fatigue crack that intersects the back wall.

Figure 1. Comparison of CIVA UT simulations and experimental measurements for the fa-
tigue crack shown in the photograph in the top row. The picture is followed by three views of
the borehole and crack in the CIVA model. The C-scan simulation results (green background)
and corresponding experimental results (blue background) are shown in the bottom row for 5
MHz and 10 MHz shear-wave scans (45°) for probes with a focal depth of 50mm and a diame-
ter of 12.7mm. The red boxes indicate reflections off the borehole, which was filled with wa-
ter for the experiments.

This work is supported by the U.S. Air Force Research Laboratory (AFRL) through Research Initiatives for Materials State Sensing (RIMSS) contract with Universal Technologies Corp., Contract No: FA8650-10-D-5210.