Fundamentals of Nondestructive Evaluation

EM 550 Ultrasonics Laboratory Spring 2023

Tasks

1. (First week) Reproduce (within a scaling factor) the example figures. Make sure you understand the steps involved.

Parameter	Value
c_{Al}	6.2 mm/μs
ρ_{Al}	2700 kg/m^3
c_w	1.5 mm/μ s
ρ_w	1000 kg/m^3
Transducer Center Frequency	1 MHz
-3dB transducer BW	400 kHz
Initial water path distance	10 mm
Crack scattering coefficient	-0.2
Noise amplitude	22 kPa RMS

2. (Second week) Extend your simulation according to your and your teammates' interest. Here are some ideas:

   - Try adjusting frequencies, bandwidths, material properties and verify that the waveform changes you predict make sense.
   - Perform a simple (physical) ultrasound experiment, and adjust the simulation to match that experiment.
   - Try simulating a wave equation that is dispersive, such as the flexural wave equation $EI\frac{\partial^4 u}{\partial x^4} = \rho\frac{\partial^2 u}{\partial t^2}$. Animate wave arrivals to observe the difference between phase and group velocities.
   - Switch to a geometry that is more relevant to your interest/application.
   - Simulate a more exhaustive list of beam paths.
   - Consider viscoelastic absorption. This is usually modeled with a complex stiffness (imaginary part is known as "Loss Modulus") that results in a complex wavespeed and complex wavenumber.
   - Consider geometric amplitude losses (roughly uniform in near-field; roughly $1/r$ in far-field).
   - Based on an ultrasonic simulation and a population of simulated flaws with different sizes (reflection coefficients), build a POD model and adjust the thresholds to obtain an acceptible POD with an acceptible false call rate.
   - The Gaussian wave packet we have used is mathematically convenient, but not very physical because it is not causal (non-zero prior to $t = 0$). Replace the Gaussian packet with a minimum-phase wavelet that is causal.
   - Use spatial (possibly multi-dimensional) Fourier transforms to model a conformal focused transducer or a delay-line phased array.

Write up what you have done and turn it in after the second week.