Modeling of Ultrasonic Wave Propagation

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Introduction: FE modeling of ultrasonic transducers and wave propagation requires time-stepping and repeated solutions – conditions that can allow numerical errors to propagate. Error-free FE models are presented so too are poorly-configured models. Experimental validation using schlieren visualization[1] is also presented.

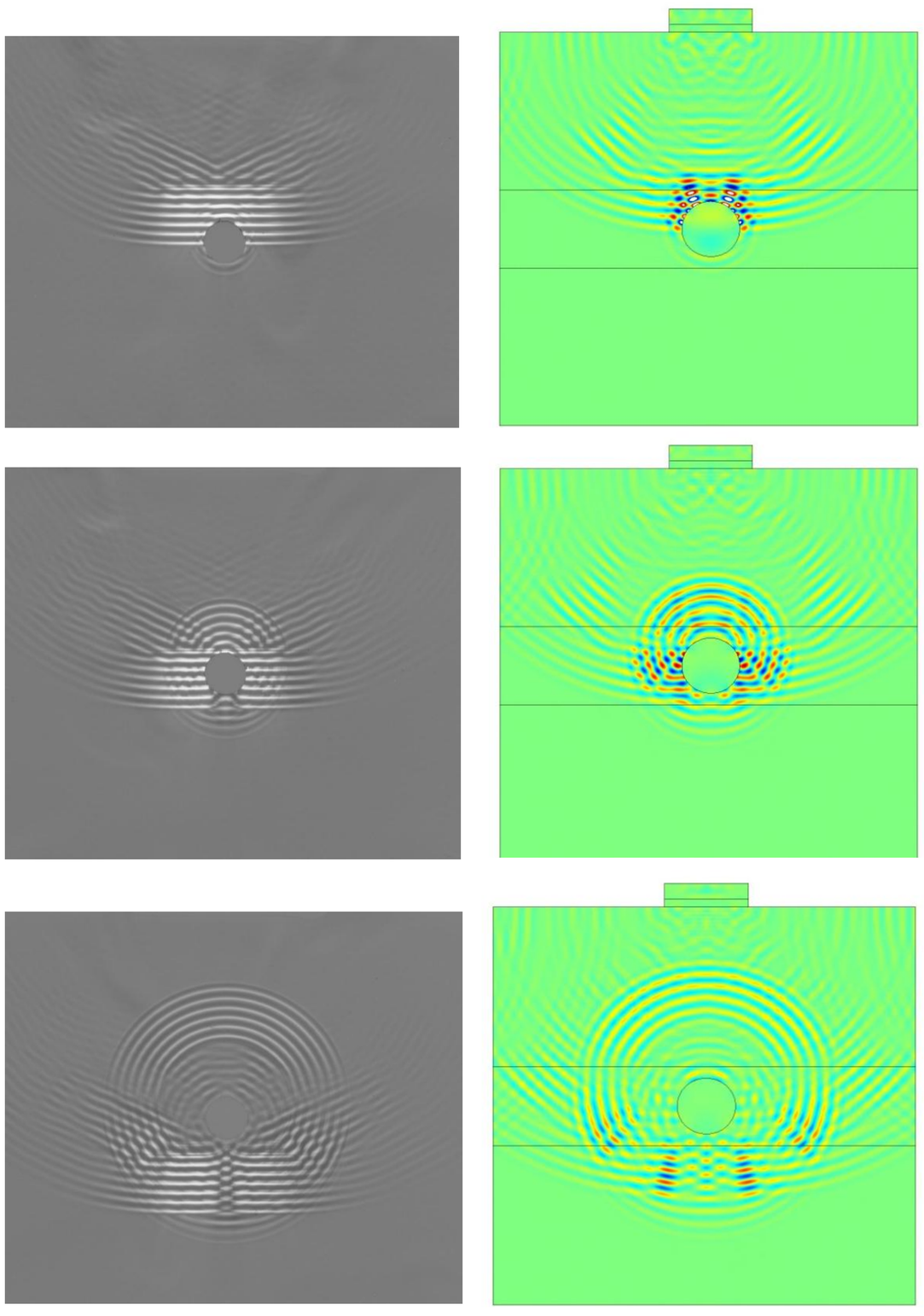

Figure 1. Photographs (left) of ultrasonic waves (500 kHz) in water being scattered by a solid aluminium cylinder viewed along its axis; equivalent FE model results (right) are also shown for a well-configured, error-free model.

FE Model: A 2-dimensional FE linear model was made using the Transient Acoustic-Structure and Piezoelectric Devices interfaces. Mesh size (~0.2 mm) was typically 5% of wavelength (3.0 mm) and the time-step (50 ns) was 2.5% of the period (2 μs) of the ultrasonic waves.

Results: Well-configured FE model results are in the images on the left along with results of schlieren visualization experiments for validation (times = 36.5, 43.0 and 52.0 μs after launching). Results of poorly-configured FE models are shown below (times = 25.0 and 52.0 μs).

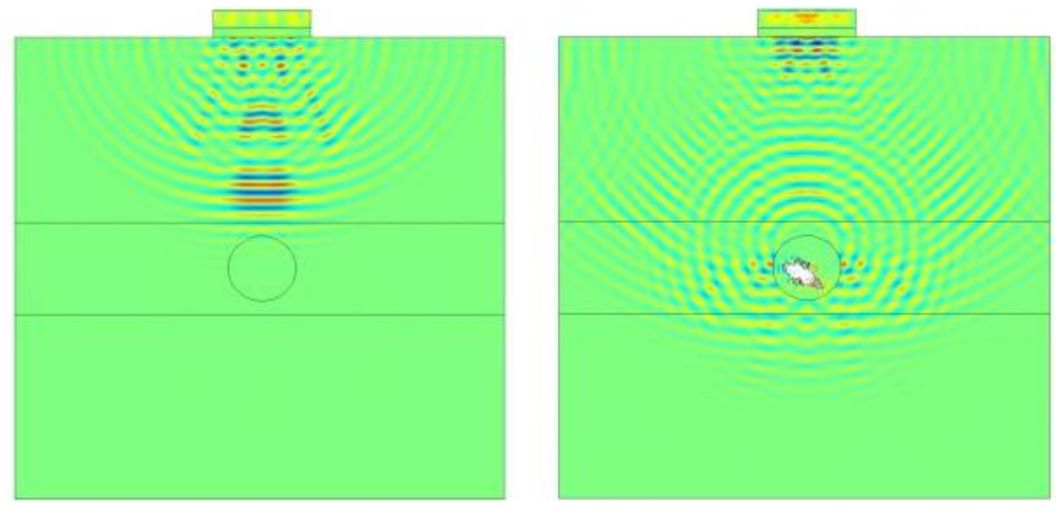

Figure 2. Results of error-prone, poorly-configured FE models. Mesh size is approximately half of the ultrasonic wavelength and time-step sometimes half the ultrasonic period.

Some errors of poor-configuration cause solver failures, others result in wave artifacts: reverberations, unexpectedly high amplitudes and non-existent waves.

Conclusions: Accurate FE models of propagating ultrasonic waves require a mesh and time-steps that are typically 10% of the ultrasonic wavelength or period. Schlieren visualization experiments are advantageous for validating FE models. Non-linear propagation generates harmonics of waves consequently these FE models are more difficult to solve because of unknown, high frequencies and short wavelengths.

Reference:

1. Andrews, D.R., SPIE 15th Cong, High Speed Photography 1982.