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Reverse-time migration of cylindrical guided ultrasonic waves for flaw imaging in pipework

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Inspection of pipework is important, in many cases mandatory, such as for the secured transport of oil and gas in the pipeline network. To achieve efficient data acquisition, an ultrasonic pipe inspection system often consists of an array of ultrasonic transducers placed in a ring setup. This will allow for quick scanning of the inspected pipe. Possible flaws can be detected based on either a predefined reflection coefficient expressed as a function of the geometrical extent of the defect or by a model-based optimization method. However, localizing and sizing the pipe flaws remain challenging tasks due partly to the strong dispersion characteristics and multiple propagation modes of the cylindrical waves.

Aiming for localizing and sizing the pipe damages, we apply the wavefield cross-correlation technique in the manner of reverse-time migration (RTM) in exploration geophysics to the cylindrical waves guided in the pipe solid. The ultrasonic wavefield imaging procedure can then be inherited and extended from imaging workflows originally developed in the computational seismology framework. Through various synthetic acquisition configurations, we show that the wavefield cross-correlation imaging can capture pipe flaws of either a point-like scatter or a finite-length crack. The imaged flaws can be very well recognizable although a considerable amount of artifacts are also observed.

The entire imaging procedure, which requires one forward and one reverse SPECFEM3D simulation, costs only a couple of minutes using 96 CPU cores. Optimizing the workflow from automatic numerical mesh generation to reducing the computing time even further is desirable for near real-time nondestructive testing. In addition, performing validation and estimation of the effective range of the RTM method using real measurement data and enhancing reconstruction quality using advanced signal and wavefield processing are important before the method can be applied in pipework inspection routines.