Ultrasonic Guided Wave Tomography of Pipes

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Abstract

This dissertation concentrates on the development of two new tomographic techniques that enable wide-area inspection of pipe-like structures. By envisioning a pipe as a plate wrapped around upon itself, the previous Lamb Wave Tomography (LWT) techniques are adapted to cylindrical structures. Helical Ultrasound Tomography (HUT) uses Lamb-like guided wave modes transmitted and received by two circumferential arrays in a single crosshole geometry. Meridional Ultrasound Tomography (MUT) creates the same crosshole geometry with a linear array of transducers along the axis of the cylinder.

Even though these new scanning geometries are similar to plates however, additional complexities arise because they are cylindrical structures. First, because it is a single crosshole geometry, the wave vector coverage is poorer than in the full LWT system. Second, since waves can travel in both directions around the circumference of the pipe, modes can also constructively and destructively interfere with each other. These complexities necessitate improved signal processing algorithms to produce accurate and unambiguous tomographic reconstructions.

This work, consequently, also describes a new algorithm for improving the extraction of multi-mode arrivals from guided wave signals. Previous work has relied solely on the first arriving mode for the time-of-flight measurements. In order to improve the LWT, HUT and MUT systems reconstructions, improved signal processing methods are needed to extract information about the arrival times of the later arriving modes. Because each mode has different through-thickness displacement values, they are sensitive to different types of flaws, and the information gained from the multi-mode analysis improves understanding of the structural integrity of the inspected material. Both tomographic frequency compounding and mode sorting algorithms are introduced. It is also shown that each of these methods improve the reconstructed images both qualitatively and quantitatively.