Full Waveform Inversion of Ultrasonic Array Data for Elastic Wave Tomography

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Background, Motivation and Objective

There is currently a demand within industry to obtain spatial maps of the internal material properties of heterogeneous structures. This is for the purpose of improving the quality assessment of manufactured components and improved in-service defect identification and characterisation. The current state of the art method uses Time of Flight [1] to reconstruct the material map, however it is limited in that there is often not a unique solution. This paper endeavours to overcome these limitations and increase the accuracy of defect imaging, sizing and location. This is achieved via a semi-analytical approach to full waveform inversion and the reversible-jump Markov Chain Monte Carlo (rj-MCMC) method

Statement of Contribution/Methods

The spatial variation in the material's interior mechanical properties is parameterised using Voronoi diagrams, where each region is assigned a local wave speed. For each transmit-receive pair of ultrasonic phased array elements the material properties along a straight ray path such as the number of regions, the length of the ray in each layer, and the wave speed in each of these layers is recorded. From this information a semi-analytical 1D model is used to approximate the A-scan that would arise from the ultrasonic phased array inspection of this material. To evaluate the distance between the modelled and observed A-scans an adapted Pearson Correlation Coefficient is calculated and is used as a basis for the objective function. The material parameterisation is perturbed iteratively using the rj-MCMC method to minimise this objective function. Due to the Bayesian framework of the rj-MCMC, a posterior distribution of material maps is obtained from which the internal structure of the component can be approximated and the uncertainty attached to this approximation quantified. The resulting map is used in conjunction with an imaging algorithm to produce a more reliable reconstruction of defects.

Results/Discussion

The data set used to test the above methodology arises from a finite element simulated through-transmission inspection of a locally isotropic layered medium. Figure 1 shows the image obtained from the map reconstructed from a medium composed of 4 layers (5700, 6100, 5010, 5900 m/s). For a random heterogeneous material with a 4mm void, we can obtain a flaw error of 0.9mm which is two-fold improvement of 1.8mm obtained from Time of Flight and a sevend-fold improvement of 8.2mm from standard TFM.

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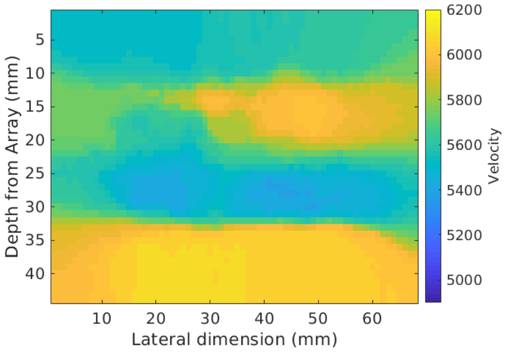

[1] K M M Tant and E Galetti, A J Mulholland, A Curtis and A Gachagan. A transdimensional Bayesian approach to ultrasonic travel-time tomography for non-destructive testing. *Inverse Problems,* 34(9), 2018.