Multi-element ultrasonic evaluation of scattering solids by reflection matrix analysis

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Background, Motivation and Objective

Multiple scattering due to strong heterogeneities of the microstructure make ultrasonic testing of forged metal alloys often difficult. Indeed, ultrasound imaging is based on the assumption that the RF signals come from single scattered waves only, so that there is a one-to-one correspondence between depth and time. Multiple scattering breaks this equivalence; as a consequence, the echo of a defect is harder to distinguish from structural noise. Thus, an estimation of the proportion of single versus multiple scattering would be a valuable indicator to assess the quality of ultrasonic inspection.

Statement of Contribution/Methods

In this work, we present several estimators of the single-to-multiple scattering ratio, obtained by analyzing the scattering reflection matrix. Data were either numerically simulated, or acquired by actual ultrasonic measurements on samples of interest (TA6V and Ti17 titanium alloys billets, 3-MHz linear probe of 128 transducers). Our simulation is an acoustic adaptation of the coupled-dipole method, also called Multiple Scattering Theory, with scatterers size comparable to the probe wavelength and medium length ranging from one half to several scattering mean-free paths.

Results/Discussion

Two estimators are compared. The first one, introduced by Aubry and Derode[1] and rearranged by Baelde & al. [2] consists in projecting the data matrix onto a theoretical subspace of single scattering. More than just estimating the single scattering proportion by taking the norm of the projection on the subspace basis, this method also enables to isolate single scattering information. The second method, built by Badon & al.[3], projects the data matrix in a focused basis to extract the local scattering parameters. In this basis, single scattering appears on the main diagonal of the matrix, whereas multiple scattering results in non-diagonal elements.

In both titanium alloys billets, single scattering proportion is found to be in the range between 0.3 and 1 depending on the chosen estimator, depth and probe direction for anisotropic samples. This low minimum value highlights the necessity to filter multiple scattering in a non-destructive testing context.

The results are discussed in relation to the scattering parameters such as the diffusion constant and the scattering mean-free path.

References

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[3] A. Badon & al., *Sci. Adv.*, 2, **2016,** e1600370