Laser ultrasonics in a multilayer structure: Semi-analytic model and different examples

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Laser-generated elastic waves have been the subject of numerous experimental, theoretical, and numerical studies to describe the opto-acoustic generation process, involving electromagnetic, thermal, and elastic fields and their couplings in matter. Among the numerical methods for solving this multiphysical problem, the semi-analytic approach is one of the most relevant for obtaining fast and accurate results, when analytical solutions exist.

First, we present a multilayer model to successively solve electromagnetic, thermal, and visco-elastodynamic problems. The optical penetration of the laser line source, as well as thermal conduction and convection, are accounted for. Complex thermal and mechanical coupling conditions are considered between the upper and lower media of the multilayer. [1]

Second, different illustrations of the model uses are proposed. On the first hand, it is used for the nondestructive evaluation of bonded assemblies thanks the analysis of elastic plane waves reflected from the bonding interface [2]. On the other hand, we use it to analyze picosecond ultrasonics experiments on single micrometric carbon fiber to infer their elastic properties. Finally, we present the interest of the model for generating significant database for machine learning investigations with laser ultrasonics.

[1] R. Hodé M. Ducousso, N. Cuvillier, V. Gusev, V. Tournat and S. Raetz, Laser ultrasonics in a multilayer structure: Semi-analytic model and simulated examples, J. Acoust. Soc. Am., vol. 150, p. 2065, 2021.

The developed PYTHON code is provided for free at https://doi.org/10.5281/zenodo.4301720.

[2] R. Hodé, S. Raetz, J. Blondeau, N. Cuvillier, V. Gusev, M. Ducousso and V. Tournat, Laser ultrasonics in a multilayer structure: Plane wave synthesis and inverse problem for nondestructive evaluation of adhesive bondings, J. Acoust. Soc. Am., vol. 150, p. 2076, 2021.