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Inverse problem identification of thickness and viscoelastic properties of a film deposit by scanning acoustic microscopy

Pooyan Manoochehrnia¹, Pierre Marechal¹, Damien Leduc¹, Mounsi Ech-Cherif El-Kettani¹

¹University of Le Havre Normandie - LOMC, UMR 6294 CNRS, France

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Solving an inverse problem has been always a matter of importance. In this study, the question focuses on finding acoustic parameters of the structure and the transducer thanks to a numerical implementation of a physical model matching with the experimental ultrasonic response. In this paper, it has been tried to apply a step-by-step matching methodology, that isolates important characteristics of the ultrasonic signal and matches the model parameters (individually or as linked coefficients) with experimental signal.

A 85 μm thick layer of epoxy resin has been deposited on a glass plate of 1.66 mm thick to form a two-layered structure. The structure is characterized using scanning acoustic microscope (SAM) equipped with a plane wave transducer with a central frequency of 50 MHz. The Debye series model (DSM) has been chosen for its efficiency to calculate the reflection coefficient of the structure as a function of the frequency. This reflection spectrum is then multiplied by the Gaussian envelope of the transducer's response. Therefore, the DSM is run with 11 different parameters and its result is then compared to experimental signal.

A step-by-step, reproducible and physically consistent method has been carried out to match parameters of DSM model with experimental signal. The first set of parameters includes the central frequency (f_0), the relative bandwidth, as well as the phase-shift of the Transducer Gaussian envelope. The second set of parameters includes material acoustic parameters notably thickness (T_h), longitudinal velocity (CL), density and attenuation, both for deposit layer and substrate layer. Varying these 11 parameters, results in a quantifiable mismatch between the model and the experiment. The visual form of the resulting signal, as well as the physical consistency of parameters and the value of mismatch error, are indicators of the way ahead.

The identification consists in isolating the first reflection echo on the substrate, then identifying each surrounding echoes and fitting each of those methodically. The first step of the inverse problem concerns the transducer's response, which is modelled by the central frequency (f_0) and relative bandwidth (Δf), corresponding (in a first approach in the time domain) to the pseudo-period and echo duration. In addition, the phase shift (ϕ) of the transducer's response is updated to match to the local minima and maxima. The second step consists in the syncing of Time of Flight (ToF) inside the deposit layer, using the $(T_h/C)d$ ratio. The third step focuses on the amplitude mismatch adjustment through the mismatch between the acoustic impedance of the deposit ($(.C)d$) and that of the substrate ($(.C)s$) layers. The amplitudes of the subsequent echoes are related to attenuation of deposit layer ($\text{Alpha}d$).

Varying the model parameters as described earlier, results in a very good match between the model and experimental signal. Notably, a very good agreement between form of signals is achieved, since the time shift between echoes has been corrected, and the amplitudes have been matched.