Laser-ultrasonic characterization of plates based on discrete points in their Rayleigh-Lamb dispersion spectra

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Background – Plates and similar geometries involving two parallel surfaces like pipes, are common products and techniques for non-destructive quality inspection at different production stages are beneficial. Their characterization in terms of thickness and elastic properties is possible, based on guided ultrasonic waves, sustained in such structures. For plates these are called Rayleigh-Lamb waves, and their dispersion curves depend on longitudinal and transverse sound velocities (c_L, c_T), and the thickness (h). Dispersion curves can be measured and mathematically inverted to determine the plates' properties. This is feasible using laser-ultrasound (LUS), however non-local and time-consuming scanning procedures are necessary to obtain the dispersion curves in high detail.

Method – We are working on a LUS method to determine c_L, c_T and h of a plate, which keeps the collected information on the dispersion curves, and the complexity of the measurement at a required minimum. We propose this can be achieved by measuring two zero-group velocity resonance [1] frequencies f_{ZGV1}, f_{ZGV2} in a combination with the fundamental mode (which at high frequencies is in approximation a surface wave) frequency f_{SAW} at a specific wavenumber k_{SAW} (see Figure 1).

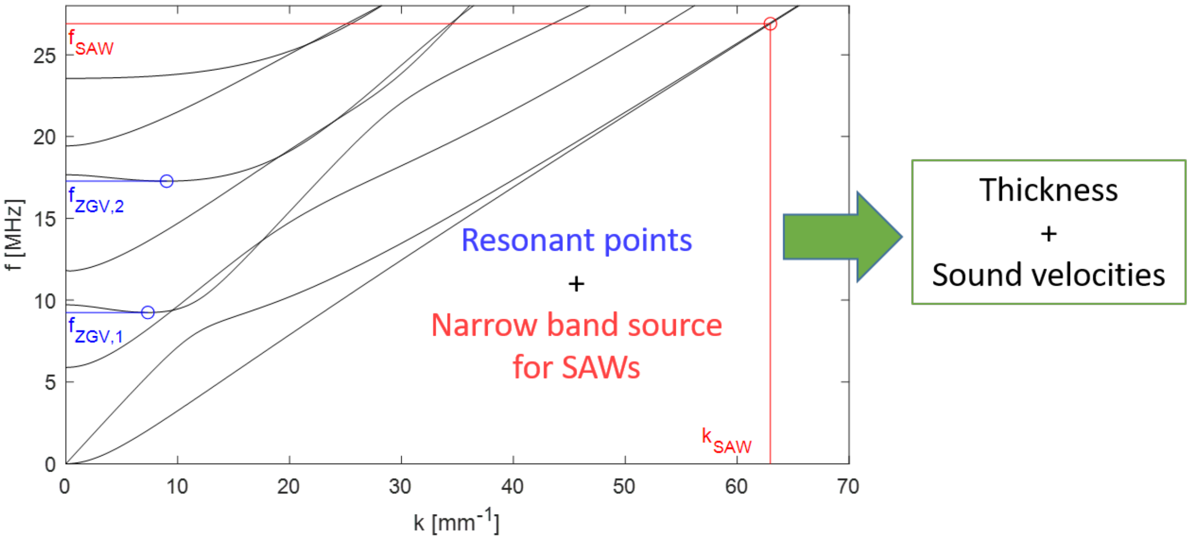

Figure 1: Dispersion curves of a plate and reduced information acquired

The latter is done in the transient grating method and related approaches by using a periodic line pattern for excitation [2,3]. The periodicity forces the k vector and the corresponding frequency of the surface wave is recorded. In a first step we use the sum of a responses from a single line at different distances to the detection point to synthesize the response of a periodic source. Due to linearity, the result is equivalent and optimum source parameters can be confirmed in experiments.

Results – We show that for plates with thicknesses in the mm-range, a finite sized periodic pattern can be used, which yields f_{SAW} at k_{SAW} set by the periodicity. If additionally, the total size of the pattern is below the half wavelengths of the ZGV resonances in the investigated plate, coupling into these resonances is achieved with the same source. When chosen appropriately, the ZGV resonances show in the lower frequency-region (e.g. $f_{\mathrm{ZGV1}}, f_{\mathrm{ZGV2}} < 10$ MHz) of the response spectrum while the SAW peak occurs in the higher region (e.g. $f_{\mathrm{SAW}} > 30$ MHz) and the can be separated. The frequencies peaks are enhanced by signal processing. From the experimental quantities, we deduce c_{L}, c_{T} and h. The influence of uncertainties in the measured quantities on the results is investigated by Gaussian error propagation.

Conclusions – The simultaneous measurement of a forced SAW resonance and intrinsic ZGV resonances can be achieved using a periodic excitation pattern. The balance of periodicity and total size of the pattern is crucial, and technical and physical limitations restrict the range of plate thicknesses and materials which can be investigated. From the single recorded response spectrum c_{L}, c_{T} and h are found. The periodic source, which in the first stage of the work is realized as a synthesis from single line responses, will replaced by a phase mask. This provides the possibility to advance from 1D periodic lines towards 2D concentric rings, with the benefit of larger displacements due to focusing of the launched waves in the centre. The aim is a single-shot, spatially resolved measurement of c_{L}, c_{T} and h.

References

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