In-situ laser-ultrasonic characterization of plates through zero-group-velocity and thickness resonances

Watzl G[(1)*], Mitter T[(2)], Grünsteidl C[(1)]

(1) Research Center for Non-Destructive Testing GmbH, Linz, Austria
(2) voestalpine AG, Linz, Austria

*Corresponding author's email: georg.watzl@recendt.at

Background – Heat treatment is a commonly used method in metal manufacturing to adjust the mechanical properties of the product. The sample undergoes various microstructural changes (e.g., phase composition, texture, grain size) during the temperature curve, whose understanding is crucial for controlling and improving the production process.

Current standard methods for sample monitoring during thermal processing are either ex-situ or require special sample preparation and therefore cannot be used on the production line. The potential of laser-ultrasound (LUS) techniques for material characterization by measuring longitudinal pulses and thickness resonances on hot and moving metal sheet samples has been demonstrated previously [1,2]. However, these methods are sensitive to thickness variations, which are common in an industrial setting, limiting their achievable accuracy. Clorennec, et al. have shown, that the Poisson's ratio of plates can be found through the measurement of two resonance frequencies of different type, which does not require knowledge on the thickness [3].

Methods – We use an adaption of the method of Clorennec, et al. to determine Poisson's ratio (ν) of plates, while the sample undergoes heat treatment. The sample is positioned in a heating chamber above an induction coil, and its surface displacement (u_z) following a short laser-pulse is measured with a vibrometer, where excitation and detection is on the same spot (see Fig.1).

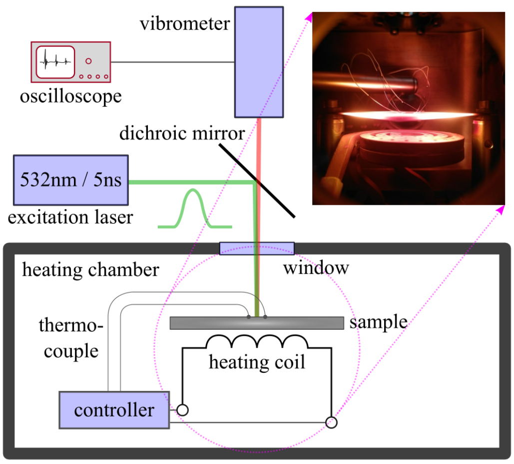

Fig. 1. Experimental setup.

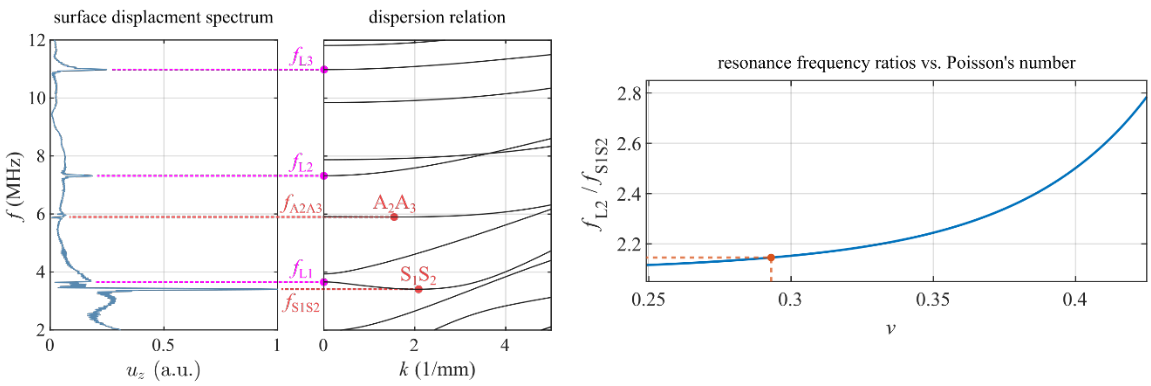

Fig. 2. Operating principle for determining Poisson's ratio of isotropic plates through local LUS measurements.

We determine a thickness resonance (L) frequency and the S_1S_2 zero-group-velocity (ZGV) mode, whose ratios yield the Poisson's number, if isotropy is assumed [4] (see Fig. 2). With additional knowledge on the thickness, the longitudinal and transversal sound velocities (c_L, c_T) can also be found. Due to the occurrence of additional resonances not used in the determination of ν, the validity of the results can be checked by comparing resonance frequencies calculated from the measured quantities with the recorded spectra.

Results – We demonstrate the measurement of Poisson's ratio during thermal processes on different metal samples and temperature curves. The measured quantities (ν, c_L, c_T) are compared to results from dilatometry and thermodynamic simulations and their correlation to microstructural changes are analysed.

Conclusions – Contact-free determination of the Poisson's ratio of plates during thermal processing can be achieved through the measurement of plate resonances with laser-ultrasound, without requiring exact knowledge on the sample's thickness. The method is robust, and the gained information can reveal material transitions in steel plates. Especially above the Curie temperature, ν is more sensitive to changes in phase composition than c_L.

References

[1] A. Moreau, et al., On-line measurement of texture, thickness and plastic strain ratio using laser-ultrasound resonance spectroscopy, Ultrasonics 40 (2002) 1047–1056. https://doi.org/10.1016/S0041-624X(02)00255-X.

[2] S. E. Kruger, E. B. Damm, Monitoring austenite decomposition by ultrasonic velocity, Mater. Sci. Eng. A 425 (2006) 238–243. https://doi.org/10.1016/j.msea.2006.03.056.

[3] D. Clorennec, C. Prada, D. Royer, Local and noncontact measurements of bulk acoustic wave velocities in thin isotropic plates and shells using zero group velocity lamb modes, J. Appl. Phys. 101 (2007) 1–6. https://doi.org/10.1063/1.2434824.

[4] C. Prada, D. Clorennec, D. Royer, Local vibration of an elastic plate and zero-group velocity lamb modes, J. Acoust. Soc. Am. 124 (2008) 203–212. https://doi.org/10.1121/1.2918543.