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High precision measurement of elastic anisotropy in metals

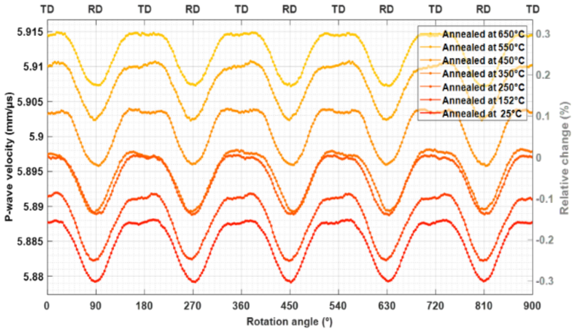
Bevis Hutchinson[1], Mikael Malmström[1], Anton Jansson[1], Peter Lundin[1]

[1] *Swerim AB, Stockholm, Sweden.*

Anisotropy of elastic wave propagation in metals is controlled by texture together with crystalline anisotropy, so laser-ultrasonic measurements can provide valuable information about a material's underlying elastic phenomena. Evidently, anisotropy cannot be deduced from a single measurement and various approaches have been used to detect and quantify this which are reviewed briefly in the introduction. These include:

- Measurements of velocity by rotating the material with respect to the instrument. This is seldom feasible in an industrial environment but we demonstrate how high precision can be achieved this way in laboratory experiments.
- Changing the wave path using a masked axicon lens or by deflecting the generating laser using galvano-mirror optics. This latter approach is well suited to industrial application such as in steel processing. Examples of this method will be presented.
- Combining different wave types having the same direction of propagation such as S_0 and S_{H0} or S_0, S_{H0} and P waves.
- Using P-waves arrivals measured after different numbers of reflections through the thickness of the plate. Although the same fixed positions are used for generation and detection, the successive pulses pass along different directions in the material.

The largest uncertainty in LUS generally comes from the measurement of distance between the two laser points. By machining the material into a cylinder using a lathe, the diameter is extremely constant as the specimen is rotated. This has allowed velocities to be measured with a precision of better than 1 part in 10,000. Results on stainless steels show excellent agreement between measured wave velocities and values calculated from the texture. Another application to quenched and tempered martensite is shown below. Tempering between 20°C and 650°C causes reduction in hardness and leads to increases in stiffness and wave velocity but the anisotropy is almost unchanged.



The Galvano mirror technique is demonstrated in application to hot rolled steels where many path directions in the material can be rapidly scanned.

Finally, we discuss some limitations of texture measurements from ultrasonic measurements.