A Unified Theory of Resonance Shifts in Ultrasound Resonance Spectroscopy

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ABSTRACT:

Ultrasound resonance spectroscopy (URS) is an emerging technique for on-line nondestructive characterization of sheet metals. By means of lasers or electromagnetic acoustic transducers, resonance frequencies of each through-thickness wave mode are measured. For each wave mode, the resonance spectrum of a homogeneous and perfectly elastic sheet sample will observe the regular pattern $f_n = nf_1, (n = 1, 2, 3, \ldots)$, where f_1 is the fundamental resonance frequency and f_n is the frequency of the n-th resonance. Both through-thickness inhomogeneity in crystallographic texture and ultrasonic attenuation (due to dislocation damping and grain scattering) in the sheet metal lead to shifts of resonance frequencies from the regular pattern. Conversely, the frequency shifts shed light on through-thickness texture gradient and ultrasonic attenuation, which, as a function of frequency, carries information on meso- and microstructures such as grain size and dislocation densities. In this paper a mathematical theory that incorporates both texture and attenuation effects is developed for resonance shifts in ultrasound resonance spectroscopy as applied to orthorhombic sheets of cubic metals. For each wave mode, a formula which expresses f_n in terms of the attenuation and the depth dependence of crystallographic texture is derived. The frequency formula is then examined against results of URS measurements on several copper samples. This paper reports joint work with Chi-Sing Man (mclxyh@ms.uky.edu), University of Kentucky.