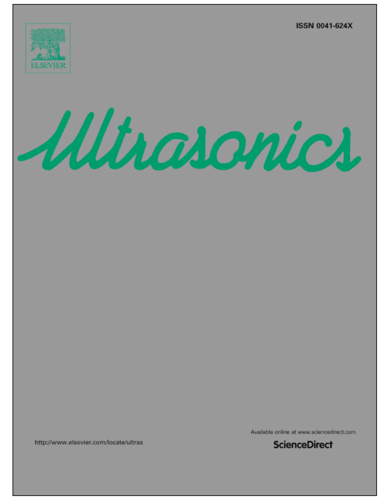

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Semi-analytical modeling of anchor loss in plate-mounted resonators

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Abstract

A semi-analytical technique for estimating the energy loss in a resonator mounted to an infinite plate substrate is proposed in this paper. In a plate, only Lamb waves have to be considered, leading to a simplified characterization of the energy carried away from a vibrating source on the plate surface. Instead of employing absorbing elements at the boundaries of the plate-resonator finite element model, it is shown how the semi-analytical approach of stitching together analytical Lamb wave expressions to the finite element model can be utilized. The approach is demonstrated for single and double cantilever configurations on a plate. The results have excellent agreement with those of conventional transient finite element simulations.

Keywords: Micro-resonator, anchor loss, Lamb waves, semi-analytical, FEM

1. Introduction

Damping in miniature resonators (e.g. vibratory gyroscopes) is a consequence of many factors and for the designer of such devices it is important to determine the dominant mechanisms that contribute to energy loss [1]. Energy loss in a vibratory gyroscope due to the interaction with the substrate to which it is mounted, commonly termed *anchor loss*, has been widely studied [2–4]. Most treatments, however, have assumed a semi-infinite medium due to the small dimensions of the resonator compared to the substrate thickness [5]. Recently reported high quality factor resonators, though, typically have resonant frequencies from a few kilohertz up to several hundred kilohertz [6–9, 4], and due to the wavelengths involved, the substrate is more accurately treated as a plate, not as a semi-infinite medium. These substrate plates are often made of fused silica or Pyrex glass and can therefore be treated as an isotropic medium [9, 10]. In any case, it is common practice to create a model of the resonator that includes a small segment of the plate with a finite element (FE) software in conjunction with absorbing boundary elements [11, 5]. As an alternative to implementing absorbing boundary elements, semi-analytical methods have been developed in which such elements are replaced by analytical expressions for Lamb waves [12]. By means of a modal superposition of all possible Lamb waves, any displacement and stress field can be represented due to the

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