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Analysis of Thin Rod Acoustic Wave Gravimetric Sensors

Zuoqing Wang[1,3], Martin Viens[2], Cheng-Kuei Jen[1], David Cheeke[2,4] and Yuan Liu[2]

[1]IMI, National Research Council, Boucherville, Quebec, Canada J4B 6Y4
[2]Dept. of Physics, University of Sherbrooke, Sherbrooke, Quebec, Canada J1K 2R1
[3]Dept. of Electrical Eng., McGill University, Montreal, Quebec, Canada H3A 2A7
[4]Dept. of Physics, Concordia University, Montreal, Quebec, Canada H3G 1M8

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An analysis based on a perturbation theory for evaluating the mass sensitivity, S_m, for acoustic wave probes of gravimetric sensors made of thin rods is presented. The lowest-order flexural F_{11}, torsional T_{00}, and longitudinal L_{01} acoustic modes are of interest. $S_m^V = \lim_{\Delta m_s \to 0} (1/V_0)(\Delta V/\Delta m_s)$ is found to be $-1/2\rho_s a$, $-2/\rho_s a$ and $-1/\rho_s a$ for F_{11}, T_{00} and L_{01} modes, respectively, where Δm_s is the uniformly distributed mass per unit area added to the surface of the rod; $\Delta V = (V - V_0)$, where V_0 and V are the unloaded and loaded phase velocities, respectively; ρ_s is the density and a is the radius of the rod. We show that $S_m^V = S_m^f V/V_g$, where V_g is the group velocity, and $S_m^f = \lim_{\Delta m_s \to 0} (1/f_0)(\Delta f/\Delta m_s)$, where $\Delta f = f - f_0$, of which f_0 and f are the resonant frequencies for unperturbed and mass loaded cases, respectively. This analysis can also be applied to bulk, Rayleigh surface, lowest flexural A_0 and shear horizontal SH_0 plate mode probes of gravimetric sensors. For flexural wave devices immersed in liquids we show that the mass sensitivity of the F_{11} mode is reduced but the reduction is less than that of the A_0 mode.

1. Introduction

Recently, research and development in the area of integrated acoustic gravimetric sensors based on bulk (BAW),[1] surface (SAW),[2] plate[3,4] and thin