Mode Analysis for an Immersed Quartz Tuning Fork Coupled to Acoustic Resonances of the Medium in a Cylindrical Cavity

J. Tuoriniemi, J. Rysti, and A. Salmela

Low Temperature Laboratory, Aalto University, POBox 15100, 00076 Aalto, Finland

Quartz tuning forks are precise electromechanical oscillators mass produced in variety of sizes around one millimeter for the purpose of providing the reference frequency for watches and such. Usually, they are designed to operate at $2^{15} = 32768$ Hz in vacuum at room temperature. When refrigerated to cryogenic temperatures, they may show very high Q-values beyond several millions. Immersion of such an oscillator to fluid medium changes its response due to inertial forces and dissipation exerted by the medium. This makes it very useful in studies of pure and mixed helium fluids at low temperatures.
When the wavelength of sound in the medium, determined by the frequency of oscillation and the speed of sound, corresponds to typical dimensions of the fluid volume, the oscillator may produce standing acoustic waves, observed as strong anomalies in the oscillator response. This can happen in helium fluids for both first and second sound under variety of conditions. We study the character of these modes by computational methods for typical fork geometries in a cylindrical volume. Reasonable correspondence with measurements in helium mixtures both below and above 1 K is obtained. This is the regime of vigorous second sound resonances, since the speed of this unusual mode compares nicely with the typical dimensions and frequency of the tuning forks. The nontrivial geometry of the fork in the cylinder makes the problem somewhat challenging for computations.