Damping of quartz forks in superfluid ^{4}He in the zero-temperature limit

Deepak Garg[a], V.B. Efimov[a,b], M. Giltrow[a], P.V.E. McClintock[a], L. Skrbek[c], and W.F. Vinen[d]

[a]Department of Physics, Lancaster University, Lancaster, LA1 4YB, UK
[b]Institute of Solid State Physics RAS, Chernogolovka, Moscow region, 142432, Russia
[c]Faculty of Mathematics & Physics, Charles University, 180 00 Prague, Czech Republic
[d]School of Physics & Astronomy, University of Birmingham, Birmingham B15 2TT

We report that the low-drive resonant linewidths Δf of nominally 32 kHz quartz forks oscillating in He II at ∼10 mK are critically dependent on their environment and on the frequency excited. A fork still inside its own cylindrical can (with a tiny hole for fluid access) has $\Delta f \sim$ 30-50 mHz (cf. the vacuum linewidth of 28 mHz) and an approximately Lorentzian lineshape; its first overtone appears at 5.9× the fundamental frequency, with a Δf that is $\sim 10^3\times$ larger and a non-Lorentzian lineshape. A fork removed from its can and mounted inside a 10 mm ID cylindrical tube exhibits a grossly broadened fundamental resonance with $\Delta f \sim 50$ Hz, apparently formed from many overlapping resonances, each of width ∼2 Hz. The resonant frequencies and lineshapes are accurately reproducible over short times, but drift significantly over longer times. We present evidence that the drift is associated with tiny pressure variations. We note that these would give rise to tiny changes in the fluid density and the velocity of sound, shifting the pattern of nodes and antinodes in acoustic standing waves generated by the fork. For the fork in its can we have observed two critical velocities: $v_{c_1} \approx 0.6\,\mathrm{cm\,s^{-1}}$, where the drag increases; and $v_{c_2} \approx 10\,\mathrm{cm\,s^{-1}}$ where there is a clear transition from quasi-laminar to turbulent flow. The results will be discussed.