Improved Understanding of the Resonance Frequency of Vibrating-Wire Sensors

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The vibrating-wire technique has been widely applied in measurements of both viscosity and density. When tensioned by a suspended weight, or sinker, the device may be used to measure these properties simultaneously. The sensitivity to density arises mainly from the effect of buoyancy on the tension and hence resonance frequency of the vibrating wire. Earlier studies have used simplified working equations for the relationship between resonance frequency and wire tension. In this work we have employed the exact equations describing forced simple harmonic oscillations of a stiff wire under tension, and also a second-order analytical solution of those equations. We show that the exact working equation describes the actual resonance frequency of tensioned tungsten wires with improved accuracy. This finding has been validated against experimental values of the vacuum resonance frequency at prescribed tensioning forces and temperatures in the range (293 to 473) K. One consequence of this is that the independently-measured true sinker volume may be used in preference to one obtained by calibration of the assembled sensor. The remaining parameters to be obtained by calibration are then the radius of the wire and a parameter that accounts for non-ideal end conditions. The values of wire radius obtained by calibration in a liquid of known viscosity have been compared with those from independent mechanical measurements having an uncertainty of 0.2 %. These comparisons have been made for both drawn wires and centreless-ground rods of diameter 0.15 mm, and the differences are discussed in the light of SEM studies of the circularity and uniformity of the wire.