Calibration of a Vibrating Wire Viscometer for Liquids: a Step Toward an Absolute Viscometer

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A vibrating wire viscometer comprises a thin (diameter about 0.2 mm) metallic wire (about 50 mm long) clamped under tension (about 20 % of yield) between two fixed supports and immersed in the fluid. For liquids the wire is typically tungsten and, in one example,[1] is about 0.1 mm diameter and 52 mm long and tensioned to give a resonance frequency of about 1 kHz. The wire is placed in a magnetic field and driven in steady-state transverse oscillations by passing an alternating current through it. The damping arising from the fluid can be determined from either transient or steady state measurements of decay time and line-width. The viscosity is then obtained from a hydrodynamic model that also requires the resonance frequency in the absence of fluid and damping, the internal damping of the wire in vacuum, the wire radius and the wire density as well as the density of the fluid. When these parameters are known by independent means the viscometer is absolute. The vacuum resonance frequency is a parameter that is allowed to float in the analysis. For liquids the viscosity is sensitive to the wire radius and fluid density but insensitive to the value of the internal damping for which an order of magnitude estimate is sufficient. Usually, the wire radius is determined by a single calibration measurement when the wire is immersed in, typically, methylbenzene[1-5] but ideally water as demonstrated by Caetano et al.[4] In our previous work[1] we have used methylbenzene and determined the radius with a relative fractional standard uncertainty of 0.6 % that has been a major source of error in the measured viscosity with an estimated standard uncertainty of ±1 %. Independent measurements of the wire diameter can be obtained from a laser-based micrometer with variable contact force with an expanded uncertainty of 30 nm. This method was used to determine the radius of 50 mm segments of 300 mm straight center-less ground wire of nominal diameters 0.3mm, 0.4mm, 0.5mm and 0.7mm. These wires were then used to measure the viscosity of water and methylbenzene and the results compared with literature values. This approach might be used to provide an absolute viscometer for the re-determination of the viscosity of water as a function of temperature and pressure.

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