Understanding Vibrating Wire Viscometry

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Correlations of the thermophysical properties of fluids still depend strongly on accurate measurements. For viscosity measurements, the vibrating wire viscometer has served as the main experimental method for decades. A rigid theory of the instrument was developed by Retsina et al. (1987) assuming point symmetry in the flow field to obtain an analytical solution of the Navier-Stokes equation. The resulting working equation of the instrument is constrained to small amplitudes of vibration. Deviations from the theoretical behaviour of the instrument were explained by different effects like interactions with the electric measurement circuit (Padua, 1994) or non-linear characteristics of the oscillator (Aumann et al. 2000). The dependence of the viscosity on the wire's amplitude squared, observed by Wilhelm (1998), could not be explained. For slightly larger amplitudes, the Boundary Layer Theory indicates axis symmetry of the flow field which is supported by flow visualisations published by van Dyke (1982) as well as CFD simulations performed in this work. Solving the Navier-Stokes equation applying axis symmetry, a group of inertia terms remains in the equation otherwise cancelled in Retsina's solution for small amplitudes. These findings agree with the dependence of the results on the amplitude squared. In CFD simulations of the flow field, the fluid-structure interaction allows to compare the working equation of the instrument with the complete Navier-Stokes equation by means of the force exerted on the wire. Fluid properties, amplitude and frequency of the wire were varied over wide ranges in the CFD simulations. Deviations between the working equation and the CFD results define the range of *Re* numbers and amplitudes for the working equation to remain valid. Additionally, the transition at initiating the wire motion is investigated as well as the point of flow separation at the vibrating wire. This defines the operating range of the instrument.