Efficient Calibration of a Vibrating Tube Densimeter Based on Optimal Experimental Design

Ophelia Frotscher[1], Viktor Martinek[2], Sebastian Klink[1, S], Roland Herzog[2] and Markus Richter[1, C]

[1]*Applied Thermodynamics, Chemnitz University of Technology, Chemnitz, Germany*
[2]*Interdisciplinary Center for Scientific Computing, Heidelberg University, Heidelberg, Germany*
m.richter@mb.tu-chemnitz.de

Vibrating tube densimeters have proven to be fast, reliable, and comparably accurate for investigating the thermodynamic behavior of fluids over wide temperature and pressure ranges. However, the uncertainty of the measurements is tied to the working equation that translates the measured frequency into density and to the calibration measurements that are used to fit the working equation. These calibration measurements require significant effort and are often performed within an equidistant grid over the necessary temperature and pressure range. Optimal experimental design (OED) provides a way to develop a measurement plan (selection of p, T state points) that minimizes the uncertainty of the fitted parameters within a model, e.g., in the working equation for the vibrating tube densimeter. However, OED is not widely used in the field of thermodynamic property measurements. This is because its core concept does not consider the experimental process, such as different times for temperature and pressure changes in the system, e.g., including the corresponding equilibration times. Therefore, we present a VTD calibration procedure, which is based on an optimal experimental design that accounts for the time and financial expenditures, as well as the uncertainties of the measurements. Both approaches, the standard and the optimal experimental design approach, are compared based on density measurements for substances where highly accurate models exist.