Refractive Index and Solubility Control of Para-cymene Solutions

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Optical measurement techniques such as particle image velocimetry (PIV) are susceptible to optical distortions at the interface of non-index matched materials especially when curved surfaces are involved. Refractive index matched (RIM) facilities provide a means to overcome this obstacle. Para-cymene, or p-cymene (1-methyl-4-isopropylbenzene), has a low kinematic viscosity (\( \nu = 0.846 \times 10^{-4} \text{ m/s} \)), high-refractive index (\( n = 1.4875 \)), good chemical compatibility, and low toxicity at 293 K. It has been employed by several groups as a working fluid in RIM facilities, Haam et al (2000), Hassan and Domínguez-Ontiveros (2008); Huang et al (2008). Near room temperature its refractive index can be matched to several materials including three readily available and affordable solids: acrylic (\( n_a = 1.4912 \) at \( T = 293 \text{ K and 589 nm} \)), pyrex (\( n_p = 1.4727 \) at \( T = 293 \text{K and 589nm} \)), and BK-7 glass (\( n_{BK} = 1.5168 \) at \( T = 293 \text{K and 587nm} \)). To achieve a careful index matching, the experimentalist has two options: controlling the environment temperature and/or adding solvent to the working fluid. Solvents also have added benefits for techniques such as planar laser induced fluorescence (PLIF), as increased concentration of dissolved dye and, hence, intensity of fluorescence signal can be improved with solvents. Here we report data on refractive index and solubility control of para-cymene by employing binary mixtures with Cinnamic aldehyde, or cinnamaldehyde, coupled with temperature control.

Refractive indices temperature dependence and binary mixture characterization are determined in this investigation with use of a Thermo Scientific Abbe-3L refractometer, Fig. 1. This refractometer has an accuracy of \( \pm 0.0001 \) for refractive index with a range of 1.300-1.710 \( n \). The operating temperature is controlled with a bench-top chiller that is placed in close proximity to the refractometer, and has a temperature stability of \( \pm 0.1 \text{C} \) with a range of -5 to 50 \( \text{C} \). Three measurements of refractive index for each pure fluid and two binary mixtures are taken at each temperature (15 - 40 \( \text{C} \)) to increase accuracy, and the average value is reported.

![Fig. 1 Refractive index temperature dependence](image)

Depending on the nature of the liquids, various equations can be utilized for the resulting refractive index of the solution. The Arago-Biot equation estimates a solution of 99% p-cymene and 1% cinnamaldehyde per volume should provide solution with a refractive index of 1.4914. However, the refractive index of both cinnamaldehyde and p-cymene vary slightly from the standard values due to impurities in the fluids, so testing should be conducted with every batch. One set of tests done for the index matching has yielded very close refractive index matching with 2% cinnamaldehyde, Fig. 1, at 25 \( \text{C} \).

These results provide an alternative to controlling the working fluid temperature and do not necessitate operating below room temperature, which would be expensive in large facilities. Fine control of temperature is still necessary, but is now near room temperature. The solvent has the added benefit of increasing the amount of fluorescent dye that can be dissolved in the solution and hence in PLIF images the fluorescence signal is stronger, and resulting images in a complex geometry are presented.

References

