Temperature Imaging in Liquids using Thermographic Phosphor Particles

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HIGHLIGHTS

• Temperature field measurements in liquids are demonstrated using zinc oxide (ZnO) tracer particles.
• The particle size requirements for accurate temperature tracing in turbulent liquid flows are calculated.
• Particle-liquid dispersions are characterised using scanning electron microscope (SEM) imaging and laser diffraction particle sizing.
• The particle luminescence properties are investigated using spectroscopic and particle luminescence imaging techniques.
• The technique is applied to a convection experiment to measure the temperature fields in a thermal plume.

ABSTRACT

Temperature field measurements in liquids are demonstrated using ZnO thermographic phosphor particles. The particles are added to the liquid as a tracer. Following laser excitation, the temperature-dependent luminescence emission of the particles is imaged and the temperature is determined using a two-colour intensity ratio method. In this work, the particle size requirements for accurate temperature tracing in turbulent liquid flows are calculated using a numerical heat transfer model. Particle-liquid mixtures were prepared using ultrasonic dispersion and characterised using SEM imaging and laser diffraction particle sizing, indicating that the particle size is 1-2 µm. The particle luminescence properties were investigated using spectroscopic and particle luminescence imaging techniques. Using 355 nm laser excitation, the luminescence signal is shown to be the same in water and in air. However, 266 nm excitation is used to avoid spectral overlap between Raman scattering from water and the detected ZnO luminescence emission. It is shown that 266 nm excitation can be used for temperature measurements in water using mass loads as low as 1-5 mg/L, corresponding to measured particle number densities 0.5-2.5x10¹² particles/m³. Cross-dependencies of the intensity ratio on the mass load and laser fluence are also investigated. A single-shot, single-pixel temperature precision of 2-3 °C can be achieved over a temperature range spanning 50 °C. The technique was applied to a convection experiment to measure the temperature fields in a buoyant thermal plume, demonstrating the suitability of these imaging diagnostics for the investigation of thermal convection and heat transfer.

Evolving temperature fields in a thermal plume above a 10 mm x 10 mm resistance heating block. A video of the plume development will be available online as supplementary material [C. Abram et al., submitted to Exp. Fluids (2016)]