Digital particle tracking thermography of individual non-encapsulated micro thermo-liquid crystals using a multi-variable calibration approach

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A measurement technique to evaluate the color response of non-encapsulated thermochromic liquid crystal (TLC) particles is presented. Raw TLC material was used to fabricate stable non-encapsulated TLC particles that provide improved particle images compared to their encapsulated counterparts which are commercially available and widely used for TLC thermography research. A multi-variable calibration approach, making use of all three HSI color components of digital color images was used to achieve low uncertainty levels in the temperature estimation of individual particles, opening the door to simultaneous temperature and velocity tracking using 3D velocimetry techniques.

All experiments were performed at the microfluidics laboratory of the Bundeswehr University Munich (Unibw) and the TLC particles were produced at the Institute of Pharmaceutical Technology of the Braunschweig University of Technology by Shirasu Porous Glass (SPG) membrane emulsification, which allos for the production of particles with narrow size distributions [1].

Images of the micro TLC particles were acquired with a 3CCD color camera with a 24-compounded dynamic range (8-bit per sensor). A preprocessing routine was applied in order to detect particles with different color schemes, consisting of a grayscale conversion based on a weighted sum of RGB components, vertical and horizontal gradient filters to identify the edges of the particles, and a segmentation filter to identify the particle nuclei over which the color HSI color values would be measured.

The data from thousands of individual particles at different temperatures, plotted in Figure 1, was evaluated fitted to a three-dimensional third degree polynomial in order to obtain a calibration function to convert the color information to temperature.

The estimated temperatures for individual particles are plotted against the real temperature in Figure 2 along with the respective 95% confidence interval uncertainty values. It is clear from the figure that the calibration method works effectively on the particle image data, thus allowing for the precise evaluation of the flow temperature at individual points in the volume. Furthermore, this approach is the first realistically usable method to track the temperature of flow tracers with these levels of uncertainty. The only other report of temperature measurement in individual tracers was written by Park et al. (2001) [2] where they reported uncertainty results twice as high as those obtained in this study, though the confidence interval is unknown, using a sophisticated neural network calibration approach in highly seeded flow where particle tracking is rather challenging.

References