Development of a particle generator for combined particle image thermo- and velocimetry in air

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Combination of Particle Image Velocimetry (PIV) and Particle Image Thermography (PIT) is well known in experiments in liquids (Dabiri 2009). By using thermochromic liquid crystals (TLCs) as tracer particles for simultaneous PIT and PIV one can measure instantaneous temperature and velocity fields simultaneously at the same location.

The intention of our work is to adapt this promising measurement technique to air flows, which are important for many technical applications and natural phenomena. Due to the Prandtl number dependence of the flow properties in thermal flows the accomplishment of convection experiments with air as working fluid is of great interest.

The main advantage of this technique is the ability to acquire the whole temperature distribution non intrusively, i.e. without integrating thermocouples or Resistance Temperature Detectors (RTDs). Beside the fact that such probes might disturb the flow, only pointwise measurements or averaged fields obtained by spatial scanning can be measured. Another important issue is the response time, which can be of the order of milliseconds for TLCs and thus allows for high time resolution.

Moreover, by simultaneous acquisition of instantaneous temperature and velocity information the understanding of the underlying physical processes, e.g. the interaction between buoyancy and inertia forces can be improved.

In a feasibility study performed by Czapp (Bosbach et al. 2007) the practicability of this new measurement technique has been proved in a cubic Rayleigh-Bénard convection cell. However, some important technical problems were not solved so far. Due to a broad and mostly unknown size distribution the sinking velocities of the TLCs differ from particle to particle. Furthermore, the particle generation was not continuously and therefore measurements could only be conducted in closed cavities. Consequently, an improved particle generator is developed, which can continuously produce tiny unencapsulated TLC particles.

The particle generator is based on Rayleigh jet breakup and it is supposed to produce monodisperse droplets of an acetone-TLC slurry. First investigations of the extruding jet of droplets were conducted by means of Phase Doppler Anemometry (PDA). For certain parameters the production of monodisperse droplets is possible, see Fig. 1. Both histograms contain 100,000 measured droplets at Re ≈ 545 and have a bin width of approximately 3.6 µm. The difference between the two measurements is the frequency of the piezoelectric oscillator, which is integrated in the particle generator nozzle.

Further measurements for various Re at a constant frequency reveal a great dependence of the droplet diameter on the Reynolds number.

The temperature sensitive TLCs, which remained on a black plate after the acetone vaporized, were analysed at a magnification of 150x. The reversible colour change due to the temperature change induced by the illumination of the microscope is presented in Fig. 2. With increasing temperature the colour of the produced TLC particles changes from red over green to blue.

Fig. 1 Particle diameter histograms, f=5 kHz, inlay f=0 kHz.

Fig. 2 Microscope exposures of TLCs at different temperatures.

References
