Experimental studies on particle-laden jet by the use of pulsed LED in a PIV/PLIF System

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In the present work, the influence of a particle-laden jet issuing a cross-flow was investigated in order to assess the turbulent mixing progress for particles with different Stokes-number. In the experimental configuration, a turbulent round jet was injected perpendicularly into a fully developed turbulent cross-flow through a square channel. To avoid influences from the pumps and to ensure a constant flow rate, the jet and the cross-flow were fed by static pressure from separate storage tanks with overflow. The Reynolds number (Re) determined the jet diameter was 12,970 and the velocity-ratio jet to cross-flow was R = 3. Different particle sizes and densities were used to achieve Stokes-numbers between 0 - 10. The measurements were performed by using Particle Image Velocimetry (PIV) applying two double image CCD-cameras with identical focal planes. Instead of using a pulse laser for the light sheet, a focussable fibre-optic LED line light source with time control was developed. The minimum width of the light sheet was 1.2 mm at a maximum working distance of 120 mm. In order to avoid in-motion sharpness in the images the maximum pulse duration of the LED light sheet was 30 µs. In order to determine velocity information from the jet fluid and the particles, the application of fluorescent particles was required. For the determination of the jet fluid velocity the water was seeded with 40 µm non-fluorescent PMMA tracers. The clear separation between the jet fluid and the particles was enabled by a band-pass interference filter for the tracer detection and a long-pass filter for the particles. Due to the lower available light intensity in relation to a laser, lenses with a depth of field with 1 mm were deployed.

Experimental Setup

The experimental investigations were carried out using a closed-loop water tunnel, which had a measurement section (see Fig. 1) consisting of a transparent square channel with the dimensions 1000 mm x 100mm x 100 mm for the cross-flow. The round jet duct had a diameter of d = 11 mm. The experiments were realized at a constant velocity ratio R=3 with Re= 50,000 (cross-flow), Re=12,970 (jet) and a water temperature of 23°C. To ensure a constant flow rate, the circular casing pumps (not shown in Fig. 1) hauled a higher flow rate as necessary for the measurements in their respective vessel. Each flow was controlled by an electromagnetic flow sensor and a manual control valve (not shown in Fig. 1).

The variation of the particle’s Stokes-number was realised by the use of particles with different densities and sizes. In order to use these non-fluorescent particles for PLIF, the coating with an acrylic lacquer mixed with Rhodamin in a heated fluidized bed was essential. The PIV / PLIF system consisted first of two 1280 x 1024 Pixel PCO Sensicam double shutter CCD cameras, which were aligned by using a beam splitter (see Fig. 2). To ensure high resolution images, the image resolution was 9.81 µm/Pixel. This was accomplished by two identical objectives Rodagon f75/4.5 with 95 mm extension tube. The band-pass filters ensured a separate recording of the jet fluid and the particles. For the tracer in the jet fluid a 532 nm band-pass interference filter from a Nd:YAG laser was deployed. The fluorescent particles were recorded with a 550 nm long-pass filter.

Fig. 1 Schematic diagram of the jet in cross-flow experimental arrangement.

Fig. 2 Schematic diagram of the technical camera setup

Results

To verify the light intensity distribution of the LED light sheet, the jet was seeded with non-fluorescent 40 µm PMMA tracers. The result of this first step is plotted in Figure 3. With a non-uniform light intensity distribution the number distribution profile would show, contrary to Fig. 3, obvious deviations from the expected jet concentration profile.

Fig. 3 Vertical tracer number distribution profile.

Summary

The first experiments proved the possibility of the application of pulsed LED as light sheet source in combined PIV and PLIF measurements. Due to the high current, the wavelength of the Luminous CBT-90 LED shifted from 535 nm below the characteristic transmission bandwidth of the filter. Hence, the low brightness of the tracer images turned out into an issue. In order to increase brightness in the tracer images, a substitution of the band-pass interference filter is necessary. In addition, an adjustment of the cameras in compliance with the light scattering angle of the tracer particles will take place.