Imaging Laser Doppler Velocimetry using a high-speed camera

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Introduction

Imaging Laser Doppler Velocimetry (ILDV) is a flow measurement technique which allows the measurement of the velocity in an imaging plane. It represents the planar extension of the classical dual beam LDV by crossing light sheets in the flow instead of focused laser beams. Seeding particles in the flow are illuminated from two different directions. The light scattered from the moving particles exhibits a frequency shift due to the Doppler effect. The frequency shift depends on the direction of the illumination and the velocity of the particle. The scattered signals from both illumination directions are detected using the same imaging system. The superposition of the two different frequency shifted signals creates interference on the detector and leads to an amplitude modulated signal. The modulation frequency depends on the velocity of the particle and the local crossing angle of the two light sheets. This signal is detected using a conventional high speed camera and the acquired data is analyzed using an autocorrelation based data analysis technique.

Measurements

To demonstrate the feasibility of measuring instantaneous turbulent flow fields, the velocity distribution of a turbulent jet in a water tank is measured. Two different setups were tested. For the first measurement a co-planar light sheet configuration was chosen to measure one of the in-plane velocity components of the jet. This setup facilitated a simultaneous PIV measurement using the same high speed camera and the same image data set, therefore allowing a validation of the technique. Fig. 1 shows the setup used for the in-plane velocity measurement. For the second measurement a crossed light sheet configuration was chosen to measure the out-of-plane velocity component of the jet. The measured velocity distributions for the in-plane and the out-of-plane measurements are shown in Fig. 2 and Fig. 4. The turbulent structures of the jet are clearly visible. A comparison of the in-plane ILDV measurement and the PIV measurement along a line at x=27 mm is shown in Fig. 3. The ILDV measurements show a very good agreement with the PIV measurement.

Conclusions

The jet experiment demonstrates the basic feasibility of demodulating the Doppler shift of scattered light using crossed light sheets and detecting the signal with a conventional high speed camera to measure instantaneous turbulent 2-D flow velocity distributions. In these experiments the crossing angle was reduced to 0.25° which allowed to measure a velocity range of 16 cm/s with the high speed camera operating at only 4000 fps. The measurable velocity range is only limited by the frame rate of the camera and the power of the illumination light source. From the present measurement it can be extrapolated that with a camera recording at 1 Mfps a measurement range of 25 m/s can be achieved. This makes this technique interesting to be applied in larger facilities e.g. low speed wind tunnels especially to measure the out-of-plane velocity component which is otherwise difficult to obtain.