Micro-PIV for high velocity flows

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Keywords: Micro PIV, high velocity

A new technique is presented for back-lighted micro-PIV measurements in high velocity flows of small dimensions like injection nozzles, sprays at the nozzle exit or particle impact. The technique requires only one pulsed incoherent light source of sufficiently short pulse duration (Nd-Yag laser, 5ns pulse duration illuminates a rhodamine solution in ethanol). This duration limits the maximally resolved velocity since the image pair is not acquired with one camera in straddling mode that would limit the minimal image temporal separation but with two cameras. For very fast flows temporal separations in the order of 20 nanoseconds would be needed. The pulse separation is obtained by the difference in light delay in plastic optical fibers of appropriate length. The delay is measured with a fast avalanche photodiode, figure 1.

The image separation is obtained optically by using polarized light and not electronically as in standard PIV. The light from the end of each fibre passes a polarizing beam splitter so that each light beam is polarized perpendicular to the other and traverses the object. Between the microscope objective and the cameras a second polarizing beam splitter separates the images, shown schematically figure 2.

A technique for sub-pixel alignment of the two images from different cameras is described. Provided the pulse duration of the light source is short enough there is no limit to the velocity range measurable. Exemplarily the cavitation flow in transparent injection nozzles is presented, figure 3. Refractive index matching is used to avoid the distortions caused by the cylindrical surface of the orifice. Tracers are graphite particles that have been selected from a polydisperse powder by sequential sedimentation in the size range from 3-5 µm, i.e. 2-3 times the image equivalent pixel size to modulate the light sufficiently. Cavitation appears dark on the back lit images. Incipience is at the inlet to the orifice and cavitation void extends to the exit of the nozzle. Therefore, the mean flow velocity can not be calculated from discharge measurements. The corresponding velocity magnitude is shown in figure 4. The peak value corresponds to 1.1 times the mean velocity calculated for incompressible flow.

The set-up as described can resolve velocities up to 200 m/s due to the pulse duration of the laser. The image quality is equal for both images since each camera can be shuttered. Straddling with one camera always gives a poorer second image.