Spray velocity field analysis by Optical Flow Method – An alternative to Particle Image Velocimetry

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Abstract

There are various optical measurement methods to determine the flow field of sprays. In this work the Optical Flow Method (OFM) is applied to high speed recording of a spray and is compared to the approved method of Particle Image Velocimetry (PIV). Since sophisticated results can be achieved even by simple configuration, OFM demonstrates a promising alternative to PIV. For example quantities of transient and turbulent flows can be obtained only by using a high speed camera in connection with an intense white light source.

The determination of the flow field of a gasoline injector serves as an example of a typical measurement task. It is observed in an optically accessible spray chamber in which pressure and temperature can be varied. Spray wall interactions are possible with different bottom plates. In a first step OFM and PIV were compared by two simultaneously taken light sheet recordings. This was realized through a superposition of the light from a continuous Ar^+-laser for OFM high speed recordings and a Nd:YAG double pulse laser for PIV in the center of the spray. The Mie scattering is selected by appropriate optical filters to the high speed camera and to a two frame PIV camera. In a second step an integral OFM was compared to PIV. For this experiment the spray was back-illuminated with a diffuse white light source and the taken images were analyzed by OFM. For PIV evaluation the two frames were split into a large number of windows. For each window a velocity vector is calculated by cross correlation method.

The chosen OFM analysis is founded on a method of Horn and Schnuck. The essential point of this method is the assumption that a brightness pattern does not change during motion. The resulting data term and a weighted smoothness term based on a global image is combined in an energy functional. The minimisation of this function provides the motion vectors. To analyze a large number of frames in short time the resulting minimisation problem was simplified.

The OFM is compared to PIV at fixed times during injection. Lightsheets compared with each other show comparable results. For correct optical flow analysis the choice of a suitable light power is crucial. On the one hand the entire spray field has to be illuminated, on the other hand undesirable intensity gradients have to be avoided.

In the second comparison of OFM applied to shadowgraphy with simultaneous PIV the results show a very good agreement of the velocity vectors with respect to their magnitude and direction. Due to a homogeneous back illumination of the spray there is no sensitivity to intensity gradients from the light. In the investigation of spray wall interactions, both methods show good results for analyzing vertebral structures. Single droplets bouncing off the wall can only be analyzed by PIV due to general restrictions of OFM. With increasing pressure in the chamber and consequently higher density of the spray, the OFM shows better results because of greater intensity gradients inside the spray. In addition, the increase of chamber temperature shows the same effect.

In the presented work it is shown that OFM and PIV provide comparable results. Concerning the OFM, lightsheet imaging and shadowgraphy were investigated. It turns out that OFM is especially suitable for sprays at higher densities and at increased chamber temperature levels. Furthermore OFM allows the simple investigation of transient flows, due to the possibility to analyze an entire injection process with just one single measurement. Since this method can be applied in connection with Schlieren measurement technique, flow analysis of a spray will be extended to vapor phase in near future.

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