Recent developments in two-phases fluorescence PIV: Application to the dynamic of high pressure gasoline sprays

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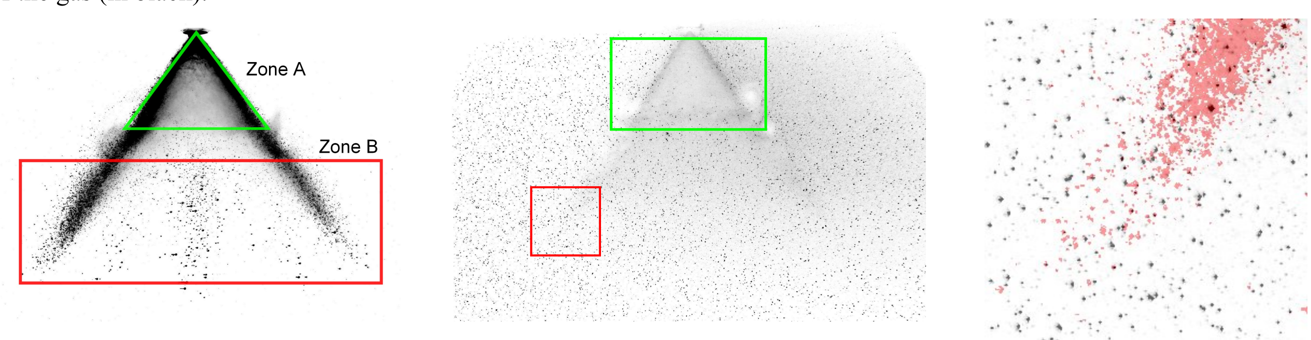
ABSTRACT

The purpose of the present work is to develop and to demonstrate the ability of the two-phase PIV by fluorescence technique for the study of two-phase flows dynamics. In particular, the dynamic of a high-pressure spray and its interaction with surrounding air is investigated in this study. For the single-phase flows, the PIV is a well-established technique to measure the velocity of the continuous phase but not easily applicable on two-phase flows without adaptation and new developments. Ten years ago, fluorescence PIV were developed to investigate dynamic of spray injection [1][2]. For phase discrimination, each phase is labelled by two different dyes allowing the acquisition of two separate pairs of images which are then analysed separately and provide the instantaneous velocity fields of the two phases. In the present paper, an extension of our previous work is proposed [2] by associating two PIV lasers at 532 nm and 355 nm in order to make separation of fluorescence signals of the two phases more efficient and then to access to velocity measurements in the denser part of the spray. This arrangement permits also an optimisation of the two PIV delays in order to account for the high velocity difference between the phases in high pressure injections. For the imaging system, the two fluorescence signals are collected simultaneously on two 12 bits Hamamatsu cameras (C9300 - 4M pixels). Two selected passband filters are placed in front of the cameras, for the discrimination of the fluorescence in each phase. To ensure a perfect overlap of the velocity measurements, image deformation technique based on 5^{th} order polynomial functions are applied on particle images to correct any differences of magnifications, orientation and optical deformation of images.

In the first part of the paper, the selection of a couple of fluorescent dyes adapted to our experimental conditions is addressed. In the second part, a novel PIV measurement based on pattern correlation is proposed to measure the velocity of the liquid phase in the dense part of the liquid jet near the injector nozzle. In the final part, our fluorescence PIV technique is validated on two high pressure gasoline injectors placed in a closed pressurized chamber (single and multi-holes injectors up to 100). bar).

The major criteria of dyes selection are: maximum of absorption spectrum close to the laser wavelengths; fluorescence signal in a spectral range close to maximum quantum efficiency of the PIV cameras; high fluorescence efficiency, especially for the dye labelling the seeding particles; distinct fluorescence emission to permit the optical filtering of the two phases; the solubility of the dyes in the liquid phase and the seeding particles. Considering all these criteria and numerous tests, our dye selection has been stopped on Stilbene 420 for the seeding particles and Pyrromethene 597 for the liquid phase.

Figure 1 presents instantaneous images in the case of single hole injector without any processing of the fluorescence signal of each dye. These images show that there is no signal from the seeding particles of the gas remaining on the spray image (Figure 1-A). The gas image (Figure 1-B) shows that the spray signal is correctly filtered in spite of the high intensity of droplets Mie scattering and fluorescence. This is confirmed in Figure 1-C by the superimposition of both phases at the location of the red rectangle plotted in Figure 1-B. Indeed, the spray droplets (in red) are clearly distinguished from the seeding particles of the gas (in black).



A **B** **C**

Figure 1 – Sample of a couple of fluorescence images of spray (A) and seeding (B) signals and their overlap (C)

For the PIV calculation on the two phases, different strategies have to be adopted. For the gas phase, the images are very similar to those obtained in PIV based on Mie scattering imaging. The velocity fields are thus evaluated using a conventionnal multi-pass cross-correlation PIV algorithm (32×32 pixels - 1.85×1.85 mm^2, 50 % overlap, validation > 90%). For the liquid phase, two complementary algorithms have been used depending on the local density of spray. In the lowest density region (Zone B - Figure 1-A), a localised PIV cross-correlation on the droplet positions is adopted [2]. In the denser part of the spray, near the injector nozzle (Zone A - Figure 1-A), this approach cannot be applied (no individual particle) and a standard multi-pass PIV algorithm failed to evaluate the velocity of the liquid. In those regions, an original PIV algorithm based on a specific management of the interrogation window taking into account the spray topology (angle, expansion) is proposed (Figure – pattern correlation method). This approach is derived from previous work on flames [5]. On the spray images, particle and pattern correlation methods are individually applied providing two velocity fields which are combined in the final step of the treatment. In Figure , a sample of an instantaneous velocity field of the liquid phase for a single-hole injector is plotted. The regions of application of each method are easily observable as a function of droplet density. In the region of intermediate density, the two approaches provide identical velocity measurements.

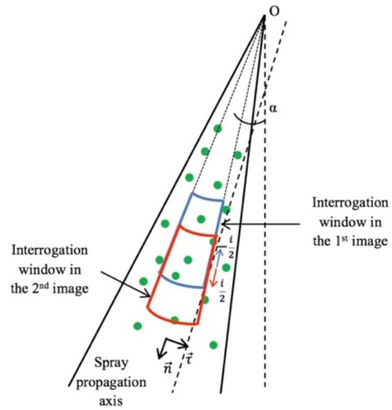


Figure 2 - Novel pattern correlation algorithm adapted to denser parts of spray and taking into account the spray topology and its radial expansion.

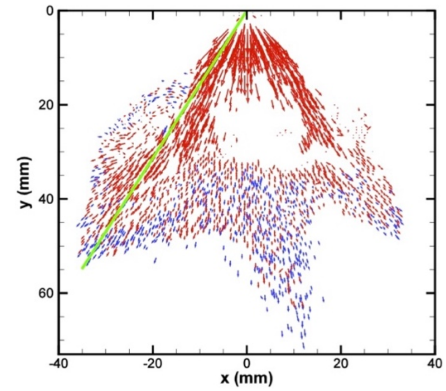


Figure 3 - Instantaneous velocity fields of spray calculated by the particle approach (blue) and by the pattern correlation method (red) 2 ms after the ASOI

The impact of gasoline injection on entrainment of surrounding gas in the external and internal part of spray is investigated for the two injectors to validate the measurements through a comparison with previous studies. An example of instantaneous measurement of both phases in the case of single hole injector is presented in Figure and demonstrates that the two-phase PIV by fluorescence is a powerful tool to measure instantaneously and simultaneously the velocity of the two phases in a dense spray and then to access to the relative spray/gas velocity in 2D which is a fundamental data to characterize the dynamic interactions between phases.

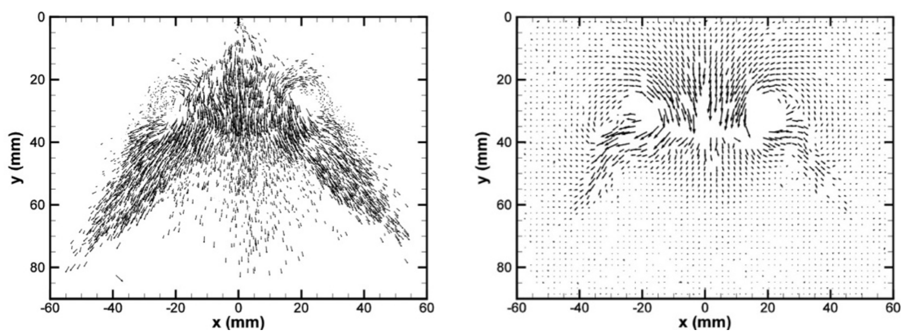


Figure 4 – Instantaneous velocity fields of the spray (left) and the gas phase (right) 4 ms after the start of injection for a single-hole injector

ACKNOWLEDGEMENTS

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