GSI Out of Focus Imaging Technique to Study Absorbing Sprays

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In 1990 an innovative 2D imaging technique to measure size of droplets in disperse sprays was proposed /1/. The innovation lays in the fact that in opposition to ordinary 2-D optical methods where well-focused images are captured, the proposed technique was based on the analysis of out-of-focus images. In out-of-focus images the droplet contours are not well defined but a peculiar pattern of fringes appears inside the droplet picture. In these conditions the picture represents the image of the scattered field, the fringes inside the droplet being the intensity oscillations of the scattered field. The angular spacing of the oscillations is quite regular (at least in forward and partially in the sideward angular regions) and inversely proportional to the droplet diameter. Thus the size of droplets could be inferred from the analysis of the images. In particular, on the basis of the Lorenz-Mie theory, a correlation between drop diameter and number of oscillation per degree was determined and the size of droplets was measured by counting the number of fringes present in each defocused drop image /1/. This approach, that we could call *Mie Scattering Imaging*, was subsequently improved /2/ and applied with good results to the estimation of fuel droplets diameter distribution in a spark ignition engine before ignition /3/.

However, the theoretical framework of the method was the Lorenz-Mie theory and, hence, the technique could be rigorously applied only in case of homogeneous droplets. On the contrary, in practical systems homogeneous droplets represent a very limit case. To overcome such a limitation, a theoretical analysis of the scattering angular patterns of non homogenous droplets was carried out and the extension of the technique to inhomogeneous droplets was assessed /4/. The extended technique, that we named *Generalized Scattering Imaging*, *GSI*, was successfully applied to transparent droplets in non-stationary vaporisation regime (i.e., with internal variation of the real part of the refractive index) /5/.

Aim of the present paper is to discuss a further extension of *GSI* to spray composed of absorbing liquids. To this aim the technique has to be modified to infer droplet diameter and imaginary part of the refractive index from the same out-of-focus droplet image, the imaginary part of the refractive index being related to the absorption of liquid. This upgrading represents a promising feature in the study of burning sprays. Droplets in combustion are in fact characterized by a variation of composition and size. For example, during evaporation/combustion of light fuel oil droplets the imaginary part of the refractive index varies of four orders of magnitude or more due to both evaporation and liquid phase pyrolysis.

The new approach is based on the measure of the visibility $\eta=(I_{max}-I_{min})/(I_{max}+I_{min})$ of the fringes inside out-of-focus droplets images, the visibility being strongly dependent on the imaginary part of the refractive index of droplets /4/. Preliminary tests have shown that visibility η permits to follow the increase of absorption in absorbing evaporating droplets composed of water with a dye dissolved at different concentrations /6/.

Specific aim of this paper is to discuss the experimental feasibility of the new method in case of absorbing hydrocarbon fuel sprays in combustion regime. The experimental set-up consists in a Nd-Yag laser sheet, a spray generator, a heating system equipped of optical accesses and a CCD (1024x1024 pixels square array) imaging system to catch the out-of-focus droplet images. Tests will be carried out on absorbing droplets in evaporating/burning regime. Size and refractive index of droplets (i.e., droplet absorption) will be measured at different locations in the spray. Droplets evaporation rate and composition will be inferred from these data.

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