High Temperature Behaviour of Emulsion Sprays Studied by GSI Technique

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The study of renewable energy sources is an important topic in the field of the combustion science. Fuels obtained from biomasses could become a valid alternative to the use of fossil fuels, also in the light of the more and more strict environmental constraints. In the outline of alternative liquid fuels, pyrolysis oils (PO) obtained from the pyrolysis of wood, generated recycling wood industry scraps, appear to be very promising as concerns their use in power plants and large diesel engines. However pyrolysis oils are characterized by high viscosity and acidity; they contain large amount of water and are thermally unstable also at ambient temperature especially in presence of air. In addition, the hydrophilic nature of pyrolysis oils prevents their mixing with fossil fuels. Thus, emulsions of POs in light oils (LO) can represent a rationale way for the utilization of biomass pyrolysis oils if the combustion properties of such kind of fuels are demonstrated.

Aim of this paper is to report the high temperature behaviour of droplets composed of emulsions of biomass pyrolysis oil in commercial diesel oil. The emulsions are prepared by mixing PO and diesel oil in appropriate conditions and in the presence of a specific additive. In the investigated emulsions the PO concentration is 30% by weight. Sprays of calibrated droplets were injected in a tubular furnace heated at different temperatures.

The *Generalised Scattering Image*, GSI, out-of-focus technique was applied to measure the properties of droplets at the exit of the furnace. It was applied the GSI technique due to its ability to measure accurately droplets size also in case of marked variations of the refractive index of droplets (i.e., their composition or internal structure). In addition, GSI is also the unique approach able to measure the imaginary part of the refractive index, *k*, from the same out-of-focus droplet image. The imaginary part of the refractive index is related to the absorption of liquid and, hence, to its composition.

This aspect is fundamental to distinguish between droplets of different composition in the same spray. Therefore, GSI technique is particularly prone to be used at high temperature and on sprays of complex fuels where droplets vary composition (i.e., optical properties) and size. In the case of sprays of PO/LO emulsions, droplets of emulsions, pure PO, and pure LO can occur simultaneously. They can be distinguished by determining their liquid absorption. In addition, due to the marked thermal instability of PO, the chemical composition of the pyrolysis oil droplets and, hence, the optical properties of the inclusions inside emulsion droplets, can change during the heating-vaporization process. Thus, the measure of the absorption of droplets can highlight chemical variations of the liquid composing the droplets. By means the unique features of GSI it is possible to really characterize a complex spray as the one under study.

This approach was applied to measure the evaporation rate and composition of sprays of calibrated droplets (D = 70 μm) of 30/70% wt PO/LO emulsions injected in a tubular furnace at different temperatures. Size and absorption of droplet were measured at the exit of the furnace at temperatures up to 350 °C. From every out of focus droplet image it was determined the droplet size, D, independently from the refractive index, by measuring the angular spacing of intensity oscillations, $\Delta\vartheta$, and using the simple relation:

$$D = 1.129\ (\lambda / \Delta\vartheta), \qquad \text{at } \vartheta = 60°,$$

where D and λ (the laser wavelength) are expressed in microns and $\Delta\vartheta$ in radians. Then, the absorption of the same droplet was inferred by measuring the oscillations visibility:

$$\eta(kD) = (I_{max} - I_{min})/(I_{max} + I_{min}),$$

that depends on the optical thickness, *k*D, of the droplet. By combining the two measurements, the size and the refractive index of every droplet in the spray were obtained.

Figure 1 shows the size distributions of emulsion droplets measured at the exit of the furnace at different temperatures. Interesting enough, the absorption of droplets measured at 350°C permitted to establish that they were formed by PO. In addition, the measured *k* value was higher respect to the pure PO one, thus showing that PO underwent combined evaporation and liquid phase polymerization during droplets heating.