PhD Proposal (2018-2021)


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International and local contexts

For combustion of liquid fuel, the energy efficiency as well as the pollutant emissions are mainly controlled by fuel droplet evaporation and local mixing. Fuel droplets evaporation is mainly controlled by the droplet and air temperatures, the relative velocity of the droplets, the amount of fuel vapor surrounding the droplets, and the temporal gradient of the air temperature in which the droplets evaporate. But, most of the actual evaporation models (for instance the Abramzon-Sirignano’s model) used in LES codes were designed from old measurements of single and large droplet evaporation rate obtained with stationary air temperature, and considering full equilibrium between liquid and gaseous phases. But the assumptions used by these models are not necessary verified in reactive two-phase flow and some large discrepancies between measurements and simulations maybe be observed. Indeed, most of the industrial injectors used for aeronautical or industrial applications are characterized by droplet size distribution with relatively small Sauter diameter (~20 to 40 microns), large slip velocities, and some strong interactions with flame reaction zones with high spatial and temporal gradients.

During the last decade, new optical diagnostics based on Rainbow Refractometry [1-3] were developed by the CORIA Laboratory (Dr. Gerard Grehan and Dr. Sawitree Saengkaew) and these techniques were applied successfully in spray flames [4, 5]. We demonstrated that droplet temperature in a Spray Jet Flame across the flame front are not well predicted by LES codes (AVBP) and the welt-bulb temperature of the droplets within the burned gases is also strongly over-predicted [6]. These results were found also by different international teams gathering into the Turbulent Combustion Spray network (http://www.tcs-workshop.org/).

These preliminary results underline the need to complete these measurements and to provide more accurate data by providing instantaneous droplet temperature measurements conditioned by the flow velocity and the droplet size. Indeed, such data are mandatory to improve the quality of the comparison and to give some insights in the improvement or modification of the evaporation models. These joint data will be obtained by coupling Instantaneous Global Rainbow Technique [5] and PDA and would provide a real breakthrough for the scientific community.
Objectives and work description

The objectives of the thesis are three-folds and will be reached by combining the complementary expertise of the supervisors. They are summarized below:

- **Provide a new database**, where droplets from different single component fuels (hydrocarbons, alcohols representative of blended bio-fuels, ...) will be characterized in terms of temperature, velocity and diameter. To achieve this database, the facility will include a pressure injector (hollow cone) discharging into an air-coflow (Figure 1-left). The co-flow temperature can be varied by an order of magnitude to enhance the evaporation rate. Working with different fuel volatilities, a large range of fuel droplet temperature is expected. This facility operates in stationary regime and the measurements will be done simultaneously by PDA and GRT for each condition. This experimental configuration characterized by well-defined boundary conditions is quite easy to simulate with a reasonable numerical cost. It will allow a good preliminary target for evaporation model validation in stationary regime.

- **Demonstrate the feasibility and the accuracy of joint PDA/GRT measurements.** This demonstration will be done on the same stationary condition. The main issue of the coupling lies on the different timing of the measurement techniques. Continuous lasers are used for PDA and the particles crossing the measurement volume trigger the PDA. At the opposite, a nanosecond pulsed laser is used for GRT [5], and the laser is the trigger of the measurement. As a consequence, the effort will be put on the coincidence of the measurement volumes, the particle density within the measurement volume and the data post-processing *a posteriori*. The effort will be made also on the individual Rainbow post-processing and this work will be done separately by Dr. Sawitree Saengkaew, in collaboration with the company “Rainbow Vision”.

- **Apply this new diagnostic in the reactive configuration (Figure 1-right).** According to the location of the measurement volume, the fuel droplets will encountered stationary or non-stationary environment, leading to different response of fuel droplet to the surrounding conditions. The experimental data will be added to the existing database and will be shared with the different numerical teams of the TCS network. A deep analysis of the droplet temperature by class of size or class of velocity will also be done.

![Figure 1](image.jpg)

*Figure 1*: $n$-heptane spray discharging into an air co-flow at ambient temperature (left). $n$-heptane jet spray flame stabilized downstream the injector with the laser beam used for GRT measurements. Droplets crossing the beam are also visible with different density according to the spatial location (right).
Availability of the experimental facility and optical diagnostics

- Non-swirling and non-confined Spray Jet Flame burner operating in atmospheric environment. Co-flow temperature will be varied from 20°C to 100°C by adding a flow heater. The burner is fully equipped with mass-flow meters and controlled by Labview interface.
- Continuous GRT system equipped with 4 laser to detect a large range of refractive index for all the different fuels investigated in the first part of the thesis.
- Commercial DANTEC PDA system (2 velocity components).
- Pulsed Nd-YAG laser to be integrated onto the C-GRT technique, according to the methodology described in [5].

Bibliography