Detailed Laser based investigations of the dynamic of spray combustion inside a multipoint injection system

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Abstract

In order to reduce pollutant emissions from aircraft engines, enhanced mixing and reduced combustion temperature using partially premixed flames is a promising technology. However, this may lead to combustion instabilities, such as blow-off or strong coupling with pressure oscillations. To study the strategies of injecting fuels through different stages, a laboratory scaled combustor has been developed and runs at atmospheric pressure with dodecane as fuel. The fuel is injected through two, co-swirling stages. The first, using full cone, pressurized nozzle with 20% of air massflow rate is called the pilot stage. The second stage consists of a swirler in which 80% of the air flows and fuel is injected through 10 equally spaced holes of 0.3 mm diameter. Air is preheated at 473K and a typical air massflow rate of 53 g/s is used for the experiments. A staging parameter α is defined as being the ratio of the mass of fuel injected through the pilot stage to the overall mass of fuel. In this paper, only one value of the staging parameter (α =60%) is deeply analyzed, even tough a different values of α (20%) is used to illustrate the different behavior observed. Different laser diagnostics are applied in both non-reacting and reacting conditions to understand the way the spray and the flame interact. A time resolved PIV measurement system is used to retrieve time resolved planar droplet velocities at 10 kHz. Furthermore, flame front position through OH-PLIF, at a lower frequency is used. Analysis of the results show appearance of a strong aerodynamic structure around frequencies of the order of 2500 Hz that is linked to the precessing vortex core (PVC). This structure still exists in reacting conditions and in some cases is strengthened when the flame is stabilized by the pilot. Reacting cases show also a peak at lower frequency (300Hz) associated to quarter wavelength of the combustion chamber. Two different flame structures are found : pilot or rim stabilized. This leads to the existence of a hysteresis phenomena with two different flame structure possible, despite having identical injection condition. Detailed analysis shows that for the rim stabilized flame, the main reaction front lies in the inner part of the chamber whereas the spray is in the outer part. For the flame stabilized by the inner recirculation zone, the main reaction front lies in the outer part of the spray in droplets stay in the inner side. This leads to different delays for evaporation and therefore different coupling with the acoustic mode of the combustion chamber. Furthermore, for one case, the PVC is strengthened, leading to a very stable flame whereas it is weakened in the second case, letting the flame be driven then by acoustic coupling.

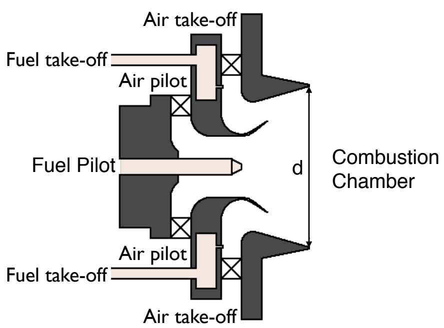

Figure 1. Schematic view of the injection device.

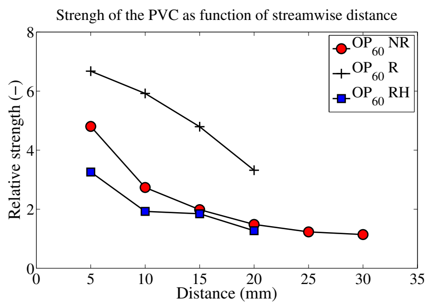

Figure 2. Evolution of the PVC as function of experimental condition.

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