Equivalence ratio measurements in kerosene-fuelled LPP injectors using planar laser-induced fluorescence

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1. Context and purpose of the experiments

Aeronautical gas turbines design is subject to new technological constraints that require high combustion efficiency associated with low pollutant emission (NO_x, CO_x and soot). Optimisation of these combustors involves the development of new injection systems by increasing the evaporation of the liquid fuel and the subsequent mixing of fuel vapour with air to enable better homogenisation of the air-fuel vapour mixture prior to combustion. Over the last two decades, innovative concepts like LPP (Lean Premixed Prevaporised) injectors have emerged as potential solutions which can match future regulations on pollutants emissions. However, while large amount of information is available in the literature on the liquid phase behaviour in these LPP systems, only few experiments have focused on the characteristics of fuel vapour. Furthermore, these studies were mainly performed with surrogate fuels or added tracers which are not necessarily representative of real aeronautical fuels (i.e. kerosene). Therefore, this indicates the need for laser-based measurements of fuel vapour concentration in a kerosene-fuelled LPP injector for various operating conditions.

The goal of the present experiments was to apply the quantitative PLIF-kerosene technique developed by Baranger et al. (2005) to a real LPP injector operating at atmospheric pressure with jet A1 fuel, for non-reactive conditions (i.e. no combustion, only fuel vaporisation). Using laser excitation scheme at 266 nm, instantaneous images of kerosene fluorescence were recorded with two ICCD cameras equipped with appropriate optical filters. Fluorescence images were processed using the dependencies found by Baranger et al. (2005) in order to obtain maps of local equivalence ratio. Influence of air temperature at the inlet (between 500 and 650 K) and overall equivalence ratio (in the range 0.12–0.44) on the spatial distribution of local equivalence ratio within the combustor was investigated.

2. Results

Figure 1 shows an instantaneous map of local equivalence ratio (Φ) obtained after data processing of fluorescence images recorded with an inlet temperature of T=650 K and an overall equivalence ratio of Φ_0=0.44. Kerosene vapour is distributed over about 80 % of the section of the premixing duct. No fuel vapour is detected at each edge of the duct, and this confinement persists axially up to a distance equal to the diameter of the premixing duct (D_0). Local equivalence ratio Φ is about 0.22 at the exit of the LPP system, which indicates that the ratio Φ/Φ_0, representing kerosene vaporisation rate, is 50 %. This suggests fairly good evaporation of the liquid fuel. For axial distance larger than D_0, local equivalence ratio decreases due to dilution with air, initially located at the periphery of the kerosene/air jet, that enters the jet and mixes with kerosene vapour. Radial expansion of the jet is limited and, therefore, it is only marginally responsible for this reduction of local equivalence ratio. Recirculation zones present at the edges of the combustor transport and trap fuel vapour at that location, which results in local equivalence ratio of about 0.1–0.15.

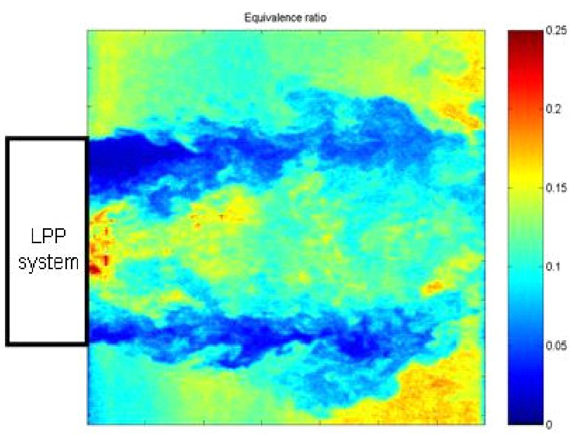

Fig. 1 Instantaneous map of local equivalence ratio for condition 3 (T=650 K, Φ_0=0.44).

Baranger P., Orain M., Grisch F. (2005), Fluorescence spectroscopy of kerosene vapour: application to gas turbines, AIAA-2005-828.