Application of TDLAS Technique to Pre-vaporized Jet A1/Air Pressure Gain Combustion

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Abstract

This paper focuses on experimental investigation of injection strategies for aiming to perform liquid-fueled pressure gain combustion (PGC). In general, the injection strategies of liquid-fueled could be classified into two types, i.e., direct injection and pre-vaporization. In the direct injection method, the liquid fuel is directly injected the combustor via atomizers. In contrast, the liquid fuel is vaporized before entering the combustor in the pre-vaporization strategy. The aviation fuel, Jet A1, is chosen as fuel in this study. The vaporization of pure Jet A1 is not practical as the required temperature could be up to several hundred Kelvin. Even if Jet A1 is vaporized, delivery of vapour-phase Jet A1 fuel into PGC combustor is another challenge. Using non-flammable gas as an assistance to vaporize the Jet A1 droplets is a possible solution to these two difficulties. Firstly, the full prevaporized temperature can be lowered. Theoretically, the required temperature for achieving fully vaporization can be lowered with increasing the concentration of non-flammable gas in the mixture with Jet A1. Secondly, the non-flammable gas can sever as a “carrier” to deliver the vapour-phase Jet A into PGC combustor. Thirdly, the non-flammable gas can heat, vaporize, mix with pure Jet A1 fuel without concerning the risk of flashback. Finally, in practice, we can introduce small amount of burned gas as the non-flammable gas.

In the pre-vaporization method, the oxidizer for combustion will be provided by a separate stream. The amount of oxidizer to attain the desired equivalence ratio is based on the concentration of vapour-phase Jet A-1 fuel. The tunable diode laser absorption spectroscopy (TDLAS) technique has the ability for real-time analysis of gas concentration in variety of harsh combustion environments. In this study, TDLAS is used to measure (i) the concentration of non-flammable gas/Jet A1 vapor and (ii) the concentration of air/Jet A1 vapor for PGC.

The information of absorption spectra data is required to perfrom TDLAS technique; however, the absorption spectra data of Jet A1 fuel is sparse due to the complexity of multi-component fuel blends. In our previous study, a series of Fourier-transform infrared (FTIR) measurements have been performed and it is found that the relatively larger absorbance occur in the region of 2850~3000 cm^{-1} and two absorbance peaks are located at 2932 cm^{-1} (3.411 μm) and 2967 cm-1 (3.372 μm). A distributed feedback (DFB) interband cascade laser (ICL), centered at 3.411 μm, was utilized as the light source in the TDLAS technique. *Prior to* TDLAS applications, the calibration work has to be done to obtain the dominant parameter: line strength. The experiment setup of calibration work was shown in Figure 1.

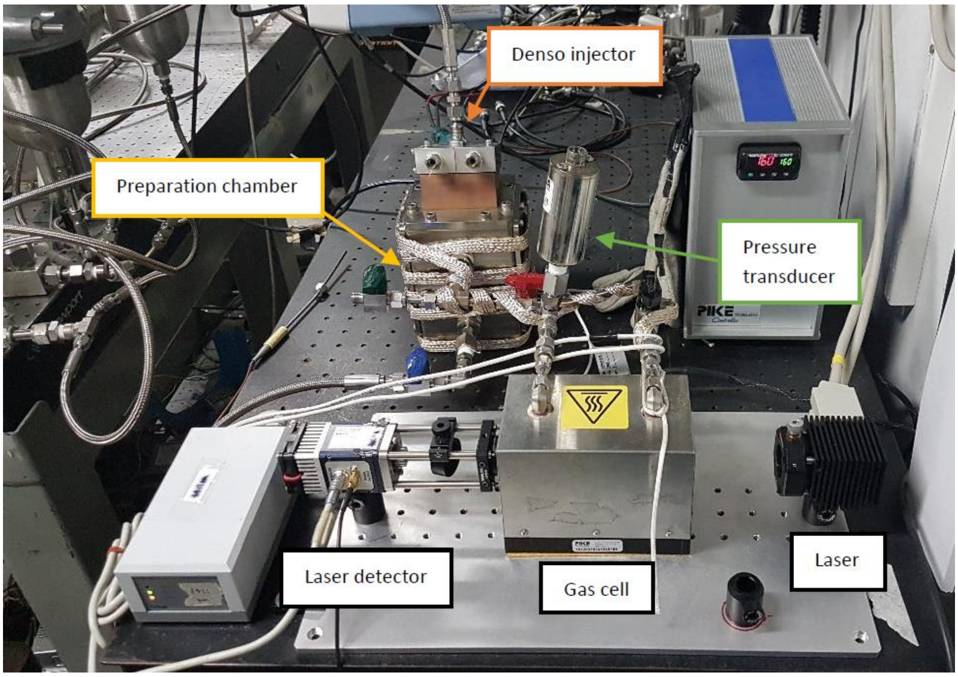

Figure 1. The experiment setup of calibration work.

In the calibration work, the analytical calculations were conducted via SUPPERTRAPP code to determine the circumstances for which the Jet A1 fuel reaches fully vaporized status. The computational results showed that when the equivalence ratio of Jet A1 fuel/nitrogen mixture is less than 6 and total pressure is 2.0 bar, the temperature above 443 K can make mixture vaporize completely. It should be noted that the SUPERTRAPP code only considers the equilibrium thermodynamic conditions and the needed time to achieve fully vaporization is unable to be obtained. Thus, the calibration work was suggested to conduct at temperatures higher than 443 K so that the mixture has a higher chance to vaporize completely during calibration work and later firing test. The line strengths at temperatures of 463 K and 488 K were obtained through the calibration work. In these two line strengths, the lower line strength is observed at higher temperature. However, the relationship cannot be confirmed solely from these datasets. And, more calibration works have to be conducted at different temperatures to provide further insights. For temperatures between 463 K and 488 K, one possible way to obtain the line strength is to interpolate from the two data sets. Subsequently, the line strength obtained from calibration work will be applied to the liquid-fueled PGC using pre-vaporization injection method and the experimental results will be presented in the full paper.

Keywords: Liquid-fuel PGC; Tunable diode laser absorption spectroscopy (TDLAS) technique; Pre-vaporization method