Experimental Investigations of the Ignition and Flame Stabilization of a Full Cone Kerosene Spray in a Lab-scale Model Combustor

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Abstract

Spark ignition of liquid fuel sprays in air and the subsequent flame kernel growth are complex processes, subjected to a variety of mechanisms. A deep understanding is essential for the development of theoretical and numerical models, which contribute to improved efficiency and emission of gas turbines or piston engines. The specific background of this study is the altitude relight of aviation gas turbines. Modern aviation combustor technologies commonly use lean combustion systems, which enforce the challenge of altitude relight. The development of such combustors requests the ability to perform numerical simulations of the ignition process, since an iterative development, including extensive testing, cannot be performed in an economical manner. In this study, the laser-induced ignition of kerosene was investigated in a lab-scale model combustor at well-defined boundary conditions. The experiments were intended to capture the transient ignition process, starting with a flame kernel and completing with a stable flame. The model combustor was a vertically arranged flow channel, which provided good optical access to enable the application of optical measurement techniques. A commercial full cone spray nozzle from Delavan/Goodrich was placed inside the combustor. This nozzle was supplied by two mass flows: a fuel mass flow and an atomization air flow. Ignition was achieved by laser-induced breakdowns. High-speed Particle Image Velocimetry (HS-PIV) was applied to the spray to measure the velocity vectors of the fuel droplets and to verify the suitability of PIV as a tool for spray characterization. An ignition probability study was carried out to determine the ignition probability of the spray flame with respect to the sparking location and to find the most reliable location for subsequent measurements. Simultaneous Planar Laser-Induced Fluorescence (PLIF) measurements on fuel aromatics and hydroxyl radicals (OH) were performed to obtain detailed information about the fuel density distribution and location of the chemical reaction zone during the ignition and flame stabilization. During the experiments the flow channel was perfused by a steady air flow at atmospheric pressure. The standard fuel was Jet A-1 aviation kerosene. Only for the PLIF measurements Exxsol D80 was used, in order to reduce the fluorescence from the fuel aromatics. Systematic variation of the air and fuel mass flows was done during all experiments to determine their impact on the ignition process. It was found that the spray features a narrow core region, where droplet densities and velocities are very high compared to the outer regions. The atomizing air mass flow turned out to have a significant impact on the spray geometry and droplet velocities. The flame stabilization process completed after approximately twenty microseconds. Flame fronts stabilize along the spray cone edge. The results are valuable data for model development and validation.

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