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Investigation of high-pressure CO_2-diluted methane/oxygen jet flame stabilization and laser-induced plasma kernel formation

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Abstract

This study explores the use of laser ignition and flame stabilization in a simplified oxygen/methane-fired, CO_2-diluted combustor under various thermodynamic conditions, to investigate challenges posed by maintaining a stable flame in direct-fired oxy-fuel supercritical CO_2 (sCO_2) combustors. Direct-fired sCO_2 cycles offer an innovative way to achieve near-total carbon capture, but flame stability issues under high pressure and temperature conditions can lead to re-ignition failures, necessitating depressurization to atmospheric levels and resulting in significant time and energy losses. In this study, we utilized a test rig featuring a seven-hole showerhead nozzle in a pressure vessel, capable of producing a jet flame at pressures up to 5 bar. We also conducted non-reactive plasma kernel generation experiments to evaluate the impact of pressure on kernel dimensions up to 25 bar. The combustor's optical access enabled plasma kernel generation and laser ignition by focusing a 532-nm laser beam from a 10 Hz Nd:YAG laser approximately 5 mm from the nozzle tip. This optical access also allowed image capture of the flame's CH* chemiluminescence to analyze flame stabilization. Our findings suggest that pressure and CO_2 dilution significantly affect flame stabilization. We also noted a decrease in the plasma kernel's diameter as pressure increased, underscoring the need for laser ignition tests at higher pressures.