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کد پوستر:

Effects of Preheating and Dilution on Kerosene Spray Flame Structure

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Abstract

To investigate the combustion of liquid fuel spray under hot-diluted conditions, a novel type rest rig was designed and constructed at Sharif University of Technology. By examining flame photographs, as well as CH chemiluminescence images, and in-field temperature measurements, effects of preheating (up to 733k) and dilution of the oxidant (as low as 17%O_2) on kerosene spray flame structure have been studied. It was observed that, in conventional combustion, spray flame emerges a double flame structure consisting of an inner and an outer flame front. On the other hand, increasing the coflow temperature or diluting the oxidant, deteriorates the inner flame front, leading to a semi-single flame structure, similar to gaseous flames. It was also noticed that in such hot-diluted environment the reaction volume is reduced, the temperature field has become more homogeneous, the peak temperature is limited to less than 1500k, and temperature fluctuations have significantly decreased, which resembles MILD combustion regime conditions, corroborating its viability for liquid fuels.

Theory and Motives

MILD (moderate or intense low oxygen dilution, also known as FLOX, CDC, and LNI) combustion is a promising technology for a clean, stable, and high-efficiency combustion. On the other hand, the combustion of liquid fuels under this combustion regime has immeasurable potentialities in industrial applications such as gas turbines, petrochemical furnaces, and steel heat treatment furnaces. Although, up to this day, multiple research groups have investigated the physical and practical aspects of MILD combustion for gaseous fuels, research on liquid fuels, in particular in their most practical manner (spray), has been so scanty. The objective of the present work is to scrutinize the phenomena involving the MILD-Spray combustion regime to contribute to the development of the technology for industrial applications.

Method of Approach

A test rig is designed and constructed at Sharif University Aerospace Advanced Combustion Laboratory (AACL) to conduct an experimental investigation on combustion of liquid fuel spray under hot-diluted conditions resembling MILD combustion regime. This test rig is mentioned as SMSTR (Sharif MILD-Spray Test Rig), which incorporates multiple subsystems, including air supply, pre-burner, liquid fuel injection, ignition, data acquisition, and cooling systems. The test section is composed of an axisymmetric central rod surrounded by an outer pipe in which the liquid fuel spray is injected vertically through a commercial pressure-swirl atomizer into the annulus jet of the coflowing air. Kerosene was used as fuel due to its sophisticated chemical composition, as well as its extensive use in industry.

The coflow composition, as well as its temperature, is determined by a Testo 327 flue gas analyzer, and flame temperature is measured by a custom-made sheathless R-type thermocouple, with a maximum outer diameter of 2mm throughout the reaction zone. Photographs of the flame are taken by a Nikon D7100 DSLR camera equipped with an ultra-narrow optical bandpass filter (410nm) for a qualitative study of CH radical concentration in the reaction zone.

Results

Based on fig.1 and fig.2, in hot-diluted conditions, an increase in coflow temperature has a profound effect on spray mechanism, causing an abrupt emergence of fuel and oxidant mixture near the nozzle orifice; hence, the structure of the flame alters from a double-flame front to a single flame front, similar to gaseous flames. Also, liftoff height is reduced to as close to the atomizer as a few millimeters, the flame volume is contracted, and the flame luminosity is considerably heightened. Moreover, according to fig.3, the flame core is extended, and its peak temperature is increased. On the other hand, dilution causes the flame volume to expand, reduces the flame intensity and luminosity, and undermines the inner flame front. It also deteriorates the flame core, decreases the peak temperature, lowers the thermal differentials, and curtails temperature oscillations. Consolidated effects of preheating and dilution modify the spray flame structure in a way that the reaction volume is reduced, the temperature field has become more homogeneous, the peak temperature is limited to less than 1500k, and temperature fluctuations have decreased. These phenomena give rise to the speculation that the MILD combustion regime is attained, even though a visible flame is observed.

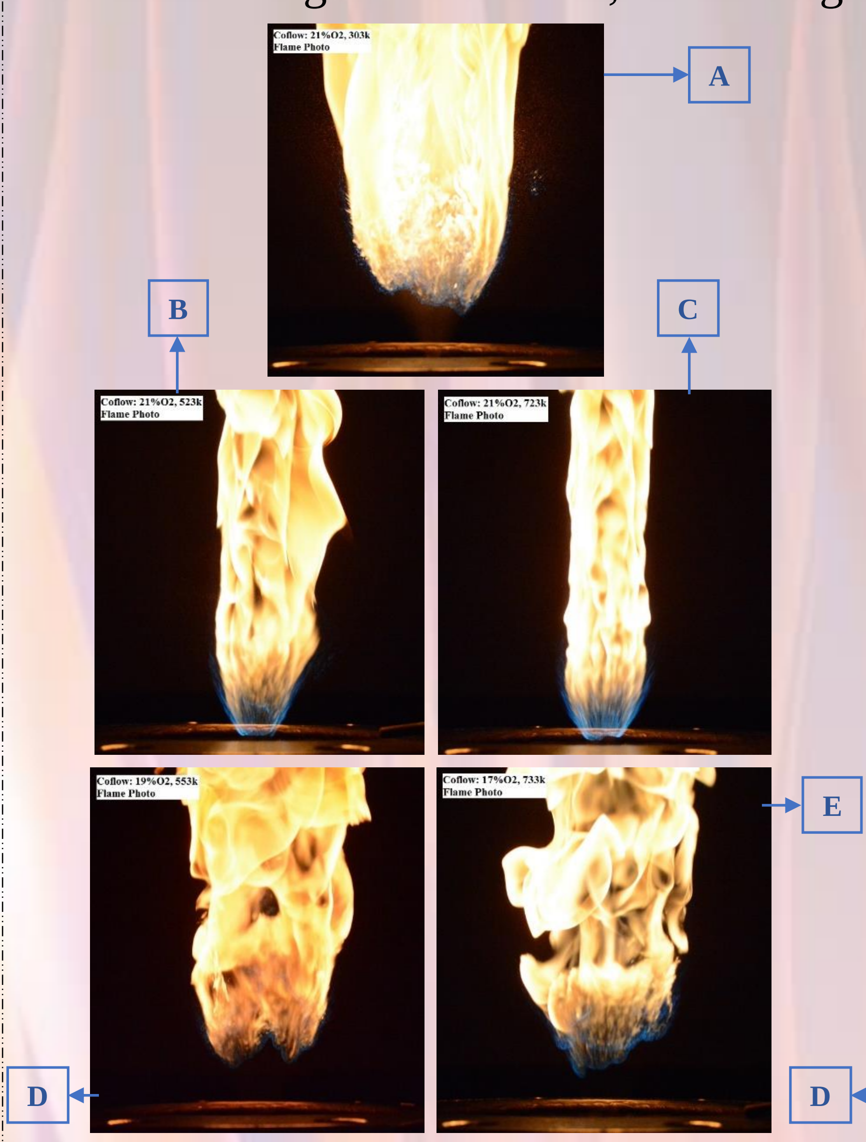

Fig.1 Spray flame photos in diff. conditions.

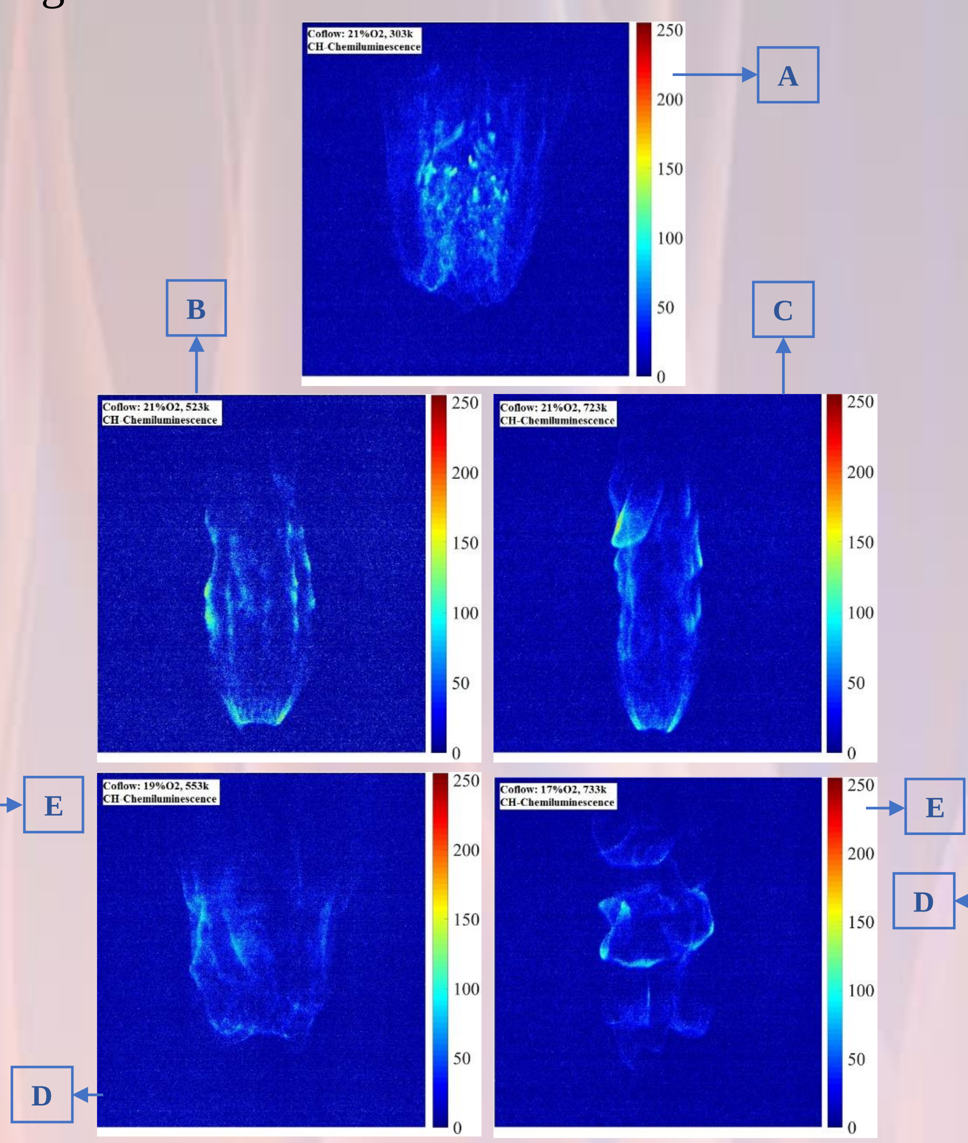

Fig.2 Spray flame CH chemiluminescence in diff. conditions.

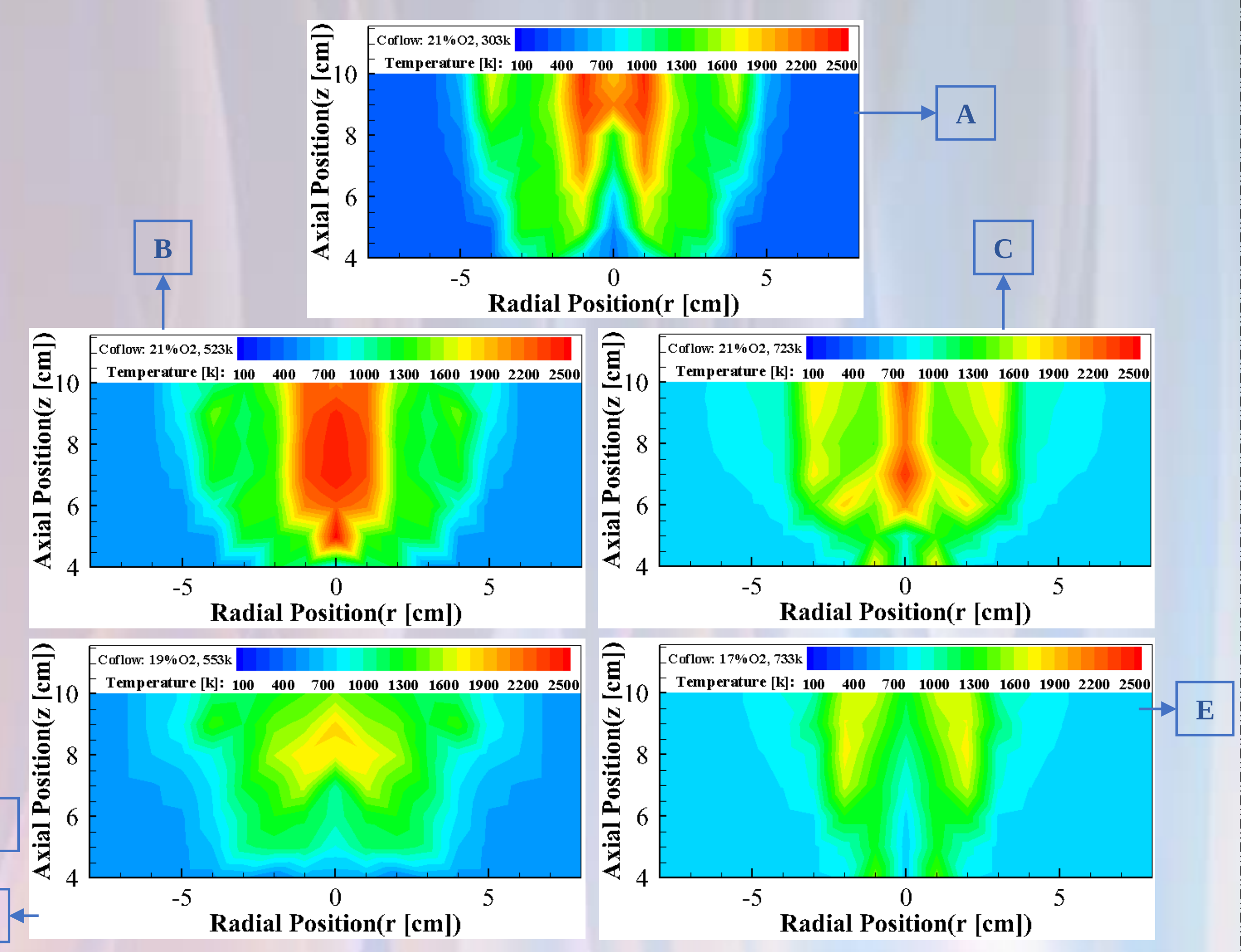

Fig.3 Spray flame measured temperature in diff. conditions.

Fig.s index	A	B	C	D	E
T_{coflow} [k]	303	523	723	553	733
% O_2 [vol.]	21	21	21	19	17