PLASMA ENHANCED COMBUSTION IN METHANE-, ETHANE-, PROPANE-, AND BUTANE-AIR MIXTURES BELOW SELF-IGNITION THRESHOLD*

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The paper presents results of temporal dynamics of hydroxyl radicals in premixed hydrocarbon-air flows excited by a nanosecond pulsed streamer discharge plasma below a self-ignition threshold. The experiments have been conducted for four different hydrocarbons – methane, ethane, propane and butane with equivalence ratio 0.1 at six different temperature points varying from 300 K to 800 K. Using laser induced fluorescence (LIF) technique the measurements of absolute OH radicals concentration dynamics is achieved by adjusting triggering synchronization between pulsed high voltage generator and Nd-YAG laser. The plasma was generated by sequential pulses of high-voltage (~20 kV), short pulse duration (~10 ns) and extremely short rise time (< 1 ns) at repetition rate of 10 Hz. The high reduced electric field guarantees efficient electronic excitation and molecular dissociation, while the picosecond scale rising time greatly improves the discharge stability and helps sustaining uniform nonequilibrium plasma. The streamer discharge in premixed hydrocarbon-air flow results in extra large concentration of OH radicals and only about 10 percent increase of gas temperatures, inferred from nitrogen second positive band system spectra. The experiments gave quantitative information on the hydrocarbon reaction dynamics under self-ignition threshold with high initial concentration of radicals.

To enhance our knowledge of fuel ignition and flame stabilization by non-equilibrium plasma, oxidation of a lean premixed methane-air, ethane-air, propane-air and butane-air mixtures under plasma discharge environment below the self-ignition threshold have been investigated experimentally using Laser Induced Fluorescence (LIF) technique. An experimental setup was built to generate a precise controlled fuel-air flow stream (pressure, temperature and equivalence ratios) and non-thermal plasma discharge. Hydroxyl (OH) radicals were formed by pulsed nanosecond discharge in the flow, which has been preheated up to 750 K at atmospheric pressure. With low energy input by plasma discharge (~ 2 mJ/pulse), the gas temperature can be controlled precisely. Via LIF, the absolute OH concentration measurement was recorded in the discharge afterglow. With different time delay between discharge and laser system, the OH dynamics were obtained. OH production is estimated to be 10^{16}cm^{-3} for pulsed average electric filed in plasma channel ~ 100 Td. Evidence has been obtained for substantial oxidation chain length existence with discharge chain initiation by radical production at combustible mixtures for the temperature range 300-800 K in lean (ER=0.1) hydrocarbon-air mixtures.

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