W2P097: DETAILED NUMERICAL SIMULATION OF FORCED PLANAR PREMIXED FLAMES
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In this work we present numerical simulations of the response of a planar premixed propane flame to acoustic perturbations. We use detailed chemical kinetics including chemical mechanisms to account for OH* formation and de-excitation via collisional quenching and light emission. The obtained oscillating response of the OH* chemiluminescence emission rate to acoustic pressure waves for the range of frequencies below and above the inverse of the flame transit time are compared to the experimental measurements of OH* chemiluminescence. Our previous work on methane and hydrogen flames have cast doubt on the validity of using measured OH* radicals in combustion experiments as an indicator of heat release. In this work we further assess the link between OH* radicals and heat release and also compare propane results to those of hydrogen and methane flames from our previous work.
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W2P098: MEASUREMENTS IN THE POST-OXIDATION ZONE OF RICH CH4/O2/N2/H2O PREMIXED FLAMES
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Auto-Thermal Reforming (ATR) of methane is one industrial process used to produce hydrogen/carbon monoxide mixtures (syngas). In such a system, the heat released by exothermic partial oxidation of methane triggers an endothermic steam reforming reaction of methane in excess to produce syngas. A typical industrial ATR reactor is composed of two main parts. The first (thermal reactor) is a pressurised combustion vessel where oxidant, usually oxygen, and hydrocarbon fuel, generally methane or natural gas, enriched with steam are injected and react through homogeneous gas phase reactions. The second part of the reactor (catalytic reactor) is filled with a catalyst bed where steam-reforming reactions take place. There are very few data on the gas phase chemical kinetics in fuel rich, steam enriched, high pressure and high temperature conditions. This work aims at providing some experimental data to improve our knowledge on the various chemical reactions occurring in the post-flame region of the thermal reactor. A laboratory scaled burner operating at atmospheric pressure has been developed to stabilize laminar flat rich premixed methane/oxygen flames above a porous material when the mixture is enriched with steam. Flames with equivalence ratio ranging from 1.5 to 2.0, oxygen enrichment ratio, defined as the oxygen molar fraction divided by the oxygen and nitrogen molar fraction, ranging from 0.3 to 0.5 and water molar fraction ranging from 0.10 to 0.30 were studied. The molar concentrations of the major species (H2, O2, N2, CH4, CO, CO2) were measured with respect to the normal distance to the flat flame front in the post-flame region using gas chromatography. Hot gases samples were collected through a micrometric quartz probe where sonic conditions were realized at the nozzle inlet to quench all chemical reactions before the chromatographer. Calibrations of the gas chromatographer were conducted at the same pressure as in the experiments using a pressure transducer in the chromatographer sampling line and several calibrated gas mixtures of the different species were investigated. For the different flame conditions explored, the measured concentration profiles are compared to one-dimensional adiabatic flame numerical simulations obtained with the PREMIX code using different detailed kinetic mechanisms. The same calculations under non-adiabatic conditions were also carried out to examine effects of heat losses to the porous burner.
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W2P099: WRINKLE FORMATION OF PREMIXED FLAMES IN STANDING ACOUSTIC FIELDS
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Ignition characteristics of lower alkane (methane, ethane, propane and n-butane) fuels and their blended fuels were investigated using a micro flow reactor with a controlled temperature profile experimentally and numerically. Knowledge on ignition characteristics for these lower alkane fuels is quite important for combustion devices which use natural gas as fuel. A quartz tube with an inner diameter of 2 mm was used as a flow reactor. By heating the tube with a hydrogen/air flat flame burner, a stationary temperature gradient (300–1300 K) was formed. A stoichiometric fuel/air mixture was supplied into the reactor. At low inlet velocity conditions (a few cm/s), a stable flame with a weak luminescence (Weak flame) is observed. It was revealed that the weak flame represented the ignition characteristics of test fuels in our previous study. Therefore, we focused on the location of the weak flame which indicated the ignitability of
mixed. Mixtures whose weak flame locating at a higher temperature region tend to be harder to ignite. The weak flame of methane located at the most downstream side, which is the highest temperature region among others. The weak flame of propane located at a higher temperature region than that of n-butane and the weak flame of ethane located at the lowest temperature region. 1-D computation was conducted using detailed chemistry. Computational flame position was defined as the position of the heat release rate peak. The computational results of atmospheric pressure conditions qualitatively corresponded to the experimental results in terms of the order of the weak flame positions. In addition, the effect of higher hydrocarbon in methane based mixture was investigated using blended fuel (methane + butane). Small addition of butane to methane significantly increased ignitability of the blended fuel and the computation reproduced this tendency qualitatively. Correlations between computed weak flame behaviors at elevated pressures and research octane numbers (RON) were examined. Further computations showed that heat release rate profiles changed dramatically with the increase of pressure and multiple heat release rate peaks were obtained in the cases of ethane, propane and n-butane. These peaks indicate the multiple oxidation of these fuels. In general, computational weak flame positions shifted to the lower temperature region with the increase of pressure. As a result, it was found that the weak flame behavior at pressures higher than 4 atm in the micro flow reactor qualitatively represented RONs of those fuels.

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Ignition characteristics of lower alkane (methane, ethane, propane and n-butane) fuels and their blended fuels were investigated using a micro flow reactor with a controlled temperature profile [1] experimentally and numerically. Knowledge on ignition characteristics for these lower alkane fuels is quite important for combustion devices which use natural gas as fuel. A quartz tube with an inner diameter of 2 mm was used as a flow reactor. By heating the tube with a hydrogen/air flat flame burner, a stationary temperature gradient (300-1300 K) was formed. A stoichiometric fuel/air mixture was supplied into the reactor. At low inlet velocity conditions (a few cm/s), a stable flame with a weak luminescence (Weak flame) is observed. It was revealed that the weak flame represented the ignition characteristics of test fuels in our previous study [2]. Therefore, we focused on the location of the weak flame which indicated the ignitability of each mixture. Mixtures whose weak flame locating at a higher temperature region tend to be harder to ignite. The weak flame of methane located at the most downstream side, which is the highest temperature region among others. The weak flame of propane located at a higher temperature region than that of n-butane and the weak flame of ethane located at the lowest temperature region. 1D computation was conducted using detailed chemistry [3]. Computational flame position was defined as the position of the heat release rate peak. The computational results of atmospheric pressure conditions qualitatively corresponded to the experimental results in terms of the order of the weak flame positions. In addition, the effect of higher hydrocarbon in methane based mixture was investigated using blended fuel (methane + butane). Small addition of butane to methane significantly increased ignitability of the blended fuel and the computation reproduced this tendency qualitatively. Correlations between computed weak flame behaviors at elevated pressures and research octane numbers (RON) were examined. Further computations showed that heat release rate profiles changed dramatically with the increase of pressure and multiple heat release rate peaks were obtained in the cases of ethane, propane and n-butane. These peaks indicate the multiple oxidation of these fuels. In general, computational weak flame positions shifted to the lower temperature region with the increase of pressure. As a result, it was found that the weak flame behavior at pressures higher than 4 atm in the micro flow reactor qualitatively represented RONs of those fuels.

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W2P100: STUDY ON IGNITION CHARACTERISTICS OF LOWER ALKANE FUELS USING A MICRO FLOW REACTOR WITH A CONTROLLED TEMPERATURE PROFILE

W2P101: IGNITION AND COMBUSTION CHARACTERISTICS OF CH₄/O₂/CO₂ MIXTURE IN MICRO FLOW REACTOR WITH A CONTROLLED TEMPERATURE PROFILE

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Oxy-fuel combustion technologies which can utilize carbon dioxide capture and sequestration are expected to contribute reducing global warming. For this, it is required to enrich our fundamental knowledge on flame characteristics of oxy-fuel combustion. In the current work, stoichiometric CH$_4$/O$_2$/CO$_2$ ($X_{O_2}/X_{CO2} = 0.62$) premixed flame which has the same laminar burning velocity of stoichiometric CH$_4$/air mixture (36.9 cm/s) is applied to a micro flow reactor with a controlled temperature profile. The present micro flow reactor technique have shown that conventional hydrocarbon fuels exhibited three kinds of flame responses, that is, normal flame, FREI (flame with repetitive extinction and ignition) and weak flame. In particular, it was shown that the general ignition and combustion characteristics of given fuel can be examined based on the weak flame behaviors.

Results show that stoichiometric CH$_4$/O$_2$/CO$_2$ ($X_{O_2}/X_{CO2} = 0.62$) mixture indicated stable flame in high velocity regime, FREI in moderate velocity regime and weak flame in low velocity regime. However the transition velocities from normal flame to FREI, and FREI to weak flame are different from those of CH$_4$/air mixture. Further examination on various dilution ratios of $X_{O_2}/X_{CO2}$ of 0.4 and 0.265, have shown that, with the increase of $X_{O_2}/X_{CO2}$ dilution ratio, transition velocity from normal flame to FREI becomes higher, and FREI to weak flame becomes lower. Furthermore, the flame temperatures of the weak flame which correspond to ignition temperatures of the mixtures shift to lower temperature region as increase of $X_{O_2}/X_{CO2}$ dilution ratio. When $X_{O_2}/X_{CO2} = 0.265$, the weak flame temperature is around 1210 K which is very close to that of CH$_4$/air mixture (1225 K), however when $X_{O_2}/X_{CO2}$ increases to 0.62 the weak flame temperature is lower than that of CH$_4$/air mixture. This indicates that mixture for oxyfuel combustion which has the same burning velocity with that of CH$_4$/air mixture is easier to be ignited.

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