Plasma assisted combustion: Interaction of a flat flame with a nanosecond dielectric barrier discharge plasma

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1. Introduction
Using of non-equilibrium Plasma-assisted for ignition, combustion and high speed flow applications are rapidly developing in the last decades due to its ability to produce a large amount of radicals and excited species. Which has a great potential in flame stabilization and emission control.

Although many studies have demonstrated the effectiveness of plasma to enhance combustion properties, the detailed enhancement mechanism is still highly unknown. Toward a better understanding of the flame behavior under plasma effect, a one dimensional flame structure setup integrated with a non-thermal plasma source has been designed.

2. Experimental setup
Fig. 1 shows schematically of the burner setup. The main parts of the setup are the plasma reactor which is the source of the non-equilibrium plasma. This reactor uses the DBD (Dielectric barrier discharge) for non-equilibrium plasma generation. The reactor consisting of four layers of electrodes separated by three layers of dielectric material as shown in the detailed view. The 1mm think perforated burner plate has holes of 0.5mm diameter with 1.0 mm pitch drilled in hexagonal pattern. The upper and lower copper layers works as (cathode) grounded electrodes, while the inner electrodes are the (anode) high voltage side. This design allows the flow to interact with the plasma by pass through the plasma micro holes meanwhile it works as a burner plate.

A non-thermal plasma is produced by a semiconductor based generator model (NPG-6/15k). An electric positive polarity pulses of 3.5 kV in amplitude, 10 ns in duration and 3ns rise time is created at a repetitive frequency of up to 20 kHz (Fig. 3). The generator is externally triggered by frequency generator model (FY22S). The voltage and the current are simultaneously monitored by data oscilloscope. The High voltage is recorded using a high-voltage probe model (HVP-18HF - 150MHz), and the current through the electrodes is measured using measured with a Pearson Coil (Model 2877)

A nanosecond repetitively pulsed plasma (NRPP) has been used to stabilize and improve the efficiency of a lean laminar premixed Methane/air flame at atmospheric pressure. We show that, the plasma produces a radical pool as well as heat that helps the flame for stabilization. Optical emission spectroscopy measurements is used to determine the concentration of the active species produced by the
plasma discharge.

3. Experimental results

Emission spectra of the plasma:

In this study, spectra of the free radicals for the plasma were recorded using spectrograph (Acton sp300) and CCD (model PI-MAX III), the spectrometer lens is focused just above the plasma reactor. Example of such spectra are presented at different air flow rates in fig. 2. The signal is average over 1000 Pulses.

It is highly noticeable that the plasma discharge of air in atmospheric pressure is very rich of excited radicals.

Fig. 2 emission spectra of the plasma for different flow velocity at atmospheric pressure.

Lean flammability limit:

Fig. 3 shows the effect of plasma at different frequencies on the lean blow-off equivalence ratio of the methane/air flame.

Fig. 3 lean blow-off equivalence ratio as a function of plasma frequency

Flame standoff height

Fig. 4 shows that plasma has been successfully reduced the stand-off height of the methane/air flame as a result of the thermal and chemical effect of the non-thermal plasma.

Fig. 4. direct image shows the comparison of the flame standoff height at the same flow conditions with (right) and without plasma (lift).

4. Acknowledgements

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5. References: