Electric Field Modification of a Diffusion Flame with Variable Electrode Geometry

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Overview

Hydrocarbon combustion creates ions which in turn can be manipulated by an electric field. The effects of an electric field vary by field strength and electrode geometry; however, the effects are not well quantified. The goal of this research is to gain insight into how an electric field modifies a diffusion flame by changing electrode geometry and electrode displacement from the Bunsen burner with a constant field per displacement and a constant flow rate of fuel. To observe changes in the flame, the intensity of the combustion product OH* (excited hydroxide) will be measured and high-speed images of the flame will be collected to observe any changes in the flow or shape of the flame.

Methodology

Changes in OH* were measured using a PLIF camera and an imaging technique called chemiluminescence. Chemiluminescence imaging filters out all light from a source besides the light emitted from a molecule of choice, in this case OH*. For each voltage value, 50 images were taken by the PLIF camera and 1000 by the high-speed camera. MatLab was used to process the sets of PLIF images on a pixel-by-pixel basis. This allowed values for average brightness (unitless) and standard deviation to be recorded for each data point per electrode. Field simulations (seen above), were created to visualize how uniform the chosen fields would be and how the flame might react.

Key Findings

• Slight increase in OH* for the Plate and Ring at 75mm and a slight decrease for the Ring at 55mm compared to other sets; however, all sets of data have a relatively consistent level of OH*.
• The electric field has a much stronger effect on the flame shape and flow properties than it does on chemistry. Although OH* levels were relatively constant, the shape of the flame and the flame stability varied depending on the electrode and electrode displacement used.
• Changes in stability can be seen in the error bars of the graphs of average brightness. Larger error is attributed partly to unstable flames with large oscillations. The ring electrode was particularly adept at enforcing stability at certain voltages (an example at 4.52 kV is shown to the right).
• At high voltages, unexpected behavior was observed in the ring and rod electrodes. The ring created an “onion” shape (seen at 6.78kV in the example to the right) which tended to spill over the burner edges. The rod suppressed the flame to the point of creating cavitation (seen at 7.53 kV in the example to the right).
• While the flame chemistry could be changing in specific regions of the flame, analyzing the entire flame at once does not bring to light anything that could be happening at that scale.

Results

The next logical step in this research is to examine further what in particular is causing the changes observed. Measurements for OH*, another combustion product, should be obtained to see if there are changes in chemistry that were not detected when examining OH*. Next, using the images from the OH* and CH* data, the brightness of the flame should be examined in layers of pixels in increasing displacement from the burner. This will provide information on how chemistry might be changing in particular regions of the flame in addition to the results of this research. Finally, changes in the flow rate may give some insight into why the shape and behavior changes with each electrode.

References


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