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Combustion Species Measurement in Electromagnetically Controlled Flame

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Project Summary

The goal of this research is to understand the effect of an electromagnetic (EM) field on a Bunsen burner flame by measuring the change in combustion species (OH^* and CH^*). Hydrocarbon combustion (methane, propane, etc.) creates charged particles (ions and electrons) through chemical ionization. These charged particles react to applied electric and magnetic fields according to Maxwell's laws. Current research has shown noticeable changes to the flame structure and particle densities in a simple open-air 1D flame. An electric field has been shown to squash flame oscillations and instabilities. The results suggest potential applications to flame control in internal combustion engines, gas turbines, or rocket engines. One theory of how the EM field affects the flame is through altering the chemical reactions, which can be observed in the concentration of intermediate reaction species such as OH^* and CH^*. These species are currently being measured on the 1D flame.

The next step in this research is to expand the work from an idealized 1D flame to a more realistic 2D conical flame, such as a Bunsen burner. Additionally, the simple grid electrode used to generate a 1D electric field will be difficult to implement in a more realistic engine setting. Thus alternative electrode designs are needed and their effects understood.

The objectives of this project are:

1) Determine how different electrode geometries change the applied EM field.
2) Determine how the EM affects the combustion reaction in a 2D flame.

The project will be mainly experimental using a standard Bunsen burner with different electrode configurations. Possible electrode configurations include rings, grids, and spokes. The diagnostics will include high-speed imaging, chemiluminescence imaging, and ion density measurements. Laser diagnostics may also be possible depending on the rate of progress and level of the student.

The RCEU student's tasks in the project include:

A) Model the electric field generated by different configurations using commercial software.
B) Obtain measurements of the flame species and behavior of a Bunsen flame in open air with different electrode configuration over a range of flow rates, fuel-to-air mixture ratios, and EM field strengths.
C) With assistance, compare the results to determine if and how much the EM field affects the chemical reactions.

Student Duties

The student will have primary responsibility for performing the modeling work, setting up the experiment, running the experiment, and collecting the data. Any necessary materials and parts will be provided. Graduate student support as well as my support will be available for the project. The last step, analyzing the data, will be a joint effort between the student, graduate student, and me. A tentative timeline for 12 weeks is as follows:

Weeks 1-2: Introduction to the lab, equipment, background of combustion and EM. Begin design of the experiment and electrode configurations.

Weeks 3-4: Order materials and set up the experiment. Meanwhile conduct computer simulations of the EM fields for the different electron configurations.

Weeks 5-6: Obtain measurements of the base flame over the predetermined range of flow rates and mixture ratios.

Weeks 7-10: Obtain measurement of the EM forced flame with the different electrodes configurations and field strengths.

Weeks 11-12: Write up the results including a poster and a journal style report.

The RCEU student is expected to be a self-motivated and diligent professional. He or she will have significant independence on the project, though assistance and direction is always available. The student is expected to contribute to group meetings, read necessary background material, and conduct any independent learning necessary to do the research. A journal club meeting occurs each week in the lab where one person is asked to prepare and present and discuss an article they have read. The RCEU student is expected to participate in the journal club and prepare at least one article presentation during the summer.

This project will provide the student a chance to conduct hands-on research in the interdisciplinary field of combustion and electromagnetics. The student will have the opportunity to see the project from beginning to end, from experimental design to documentation of the results. The work will build on topics in thermodynamics and electromagnetics learned in the classroom to provide new experiences that cannot be gained as part of a regular undergraduate curriculum or through internships and co-ops. This project is a great way to experience experimental research for future graduate pursuits.

The expected data from this project are high-speed images of the flame, chemiluminescence measurements of OH^* and CH^* species, and ion density measurements. This data will be analyzed as a function of the electrode configuration, flow rates, mixture ratios, and EM field strengths to determine the magnitude and mechanism of the EM field effect. At the end of the semester the student is expected to produce a detailed report of his or her work in journal format. I encourage submission of quality work to society or national conferences and journals.

Mentor Supervision and Interaction

During the summer semester, I spend 2-3 days a week personally working at the lab alongside my students. I may assist with their projects or do work on my own. Thus I will have regular interactions with the RCEU student. The student will also have daily interactions with the graduate students who work with me and conduct research in the lab. Direct supervision, mentoring, and evaluation of the project by me will occur once a week at the regularly scheduled project meetings. In the meetings we will discuss the current status of the project, recent results, difficulties encountered, what to do next, and address any other issues that may come up. Indirect interactions and mentoring by graduate students and I will occur throughout the semester as part of the day to day activities. The student will either report to me, or Mr. Jacobs, the graduate student working on the larger research of which this project is part of.