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Electric Field Forcing of Low-Pressure Rocket Injector Flame

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Electric Field Forcing of Low-Pressure Rocket Injector Flame

Faculty Mentor

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Previous participation in RCEU: Yes

Project Summary

The goal of this project is to study the effect DC, AC, and pulsed DC electric fields have on a pentad rocket injector flame. The Plasma and Electrodynamics Research Lab (PERL) has been studying the effect of electric fields and plasma discharges on combustion and flames for the last 5 years. We have found significant improvements to the flame are possible with high voltage fields. The field can increase the maximum blowoff velocity, decrease the minimum fuel required for combustion, and suppress low-frequency pressure oscillations due to unsteady heat release. The behaviors have benefits for high speed combustion like in ramjet engines or leaner combustion for fuel savings and emissions reduction. The work to date has been all done on simple Bunsen burners. As an effort to direct the research towards applications, the work is studying the effect of the electric field on a pentad rocket injector.

The pentad injector has a central outlet where the air oxidizer exits, and four smaller outlets angled at 45° where the methane fuel exits. The five streams meet and mix downstream to create a combustible mixture. The injector has been characterized in the past without electric field forcing. This project seeks to study the effect of the electric field on the flame behavior to develop methods to control and improve rocket engines, such as an acoustic oscillation dampener.

The project will be primarily experimental, though some basic calculations and modeling of the electric field using commercial programs may be needed. The primary properties of interest are temperature fluctuations in the chamber wall, pressure oscillations, and visible flame behavior under the electric field. Diagnostics including thermocouples, high frequency pressure transducers, infrared cameras, and high-speed cameras may be used. The student will operate the injector and associated components along with a graduate student. The student will assist with data collection and analysis. Assistance from graduate students and the professor will of course be available.

The RCEU student's tasks in the project include:

- 1) Learn proper lab safety and operation of the injector, power supplies, and diagnostics.
- 2) Obtain measurements of the flame properties and behavior as a function of the field.
- 3) Compare and analyze the data to determine quantitatively the effect of the field on the combustion process and flame behavior.

Student Prerequisites

A successful student applicant should have some experience working with Matlab, MS Excel, and hand tools. The student should be confident in their ability to conduct themselves in a safe manner



Figure 1. Pentad rocket injector with a methane-air flame on the lab bench.

as the project deals with fire and high voltage electrodes, both of which are potentially deadly. Experience writing technical document from labs reports or papers is useful. An understanding of error analysis is helpful.

Student Duties

The student will have primary responsibility for operating the experiment and collecting and analyzing the data. 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 on combustion and plasmas. Familiarization with the experiment.

Weeks 3-6: 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: Analysis and documentation of the results including a poster.

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 main expected deliverable is a poster and a detailed report of his or her work. I encourage submission of quality work to society or national conferences and journals.

Mentor Supervision and Interaction

During the summer semester, I spend 3-4 days a week personally at the lab. I may assist with the student 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 the graduate student working on the overall project.