1-1-2016

Electric Field Control of a Singing Rijke Tube Flame

Kunning G. Xu
University of Alabama in Huntsville

Electric Field Control of a Singing Rijke Tube Flame

Faculty Mentor

Dr. Kunning G. Xu, Assistant Professor, Mechanical and Aerospace Engineering
E-mail: Gabe.xu@uah.edu *Phone*: (256) 824-5083
Office: Technology Hall, Rm S234, UAH

Project Summary

The goal of this research is to test and understand the effect of a DC electric field on the acoustic behavior of a Rijke tube. The Rijke tube is a long cylinder typically made of metal often used to demonstrate and experiment with heat induced pressure waves or thermoacoustics. A heat source, either a heated piece of metal mesh or a flame is placed at one end of the tube. The heat causes expansion and contraction of the air inside the tube causing small pressure waves to bounce back and forth. When these pressure waves exist at the resonant frequency of the cylinder, the Rijke tube "sings".

The acoustic behavior of Rijke tubes are well understood thus can be used to study the interactions between acoustics and the flame. All combustion engines from cars to airplanes have acoustic waves. The flame itself releases acoustic waves through oscillations in temperature. The danger of acoustic oscillations in engines is they can sync with the temperature oscillations which produce them and grow to an unstable level that can damage the engine itself. Thus there is effort to control these thermoacoustic instabilities. Our research is in the field of plasma assisted combustion which focuses on the interactions between electromagnetic fields and plasmas with flames and combustion. Research has shown that an electric field can significantly alter the flame behavior and reduce flame oscillations, which in turn can reduce acoustic oscillations. Thus we want to study the potential of electric fields to control the acoustic oscillations of a flame by using a Rijke tube. The project will be primarily experimental, though some basic calculations and modeling of Rijke tube acoustics will be required as well.

The project may require the student to design and build an experiment or make modifications to an existing experiment. Possible diagnostics include thermocouples, pressure transducers, and a chemiluminescence emission camera. Assistance from graduate students and the professor will be available.

The RCEU student's tasks in the project include:

1) Design a benchtop Rijke tube experiment utilizing a Bunsen burner as the flame source.
2) Characterize the acoustic modes of the tube with pressure transducers and thermocouples and compare to the theoretical calculations.
3) Applied a DC electric field on the Bunsen burner and measure changes in the acoustic modes of the Rijke tube.

Student Prerequisites

A successful student applicant should have some experience with temperature or pressure measurements, either from a lab or other experience. An understanding of error analysis is helpful. Finally the student should be familiar with computer programs such as Excel, Matlab, and Solid Edge or another CAD program.

Student Duties

The student will have primary responsibility for setting up the experiment, running the

experiment, collecting the data, and analyzing the results. 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 experiment and Rijke tubes. Begin design of the experiment.

Weeks 3-4: Order materials and set up the experiment. Meanwhile determine the theoretical acoustics modes of the designed Rijke tube.

Weeks 5-6: Characterize the Rijke tube over a range of flow rates and mixture ratios without an electric field. This provides the baseline behavior.

Weeks 7-10: Obtain measurement of the electric field 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 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, the graduate student working on the larger research in plasma-assisted combustion of which this project is part of.