Flame Propagation Through Narrow Channels

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Introduction

- Hydrogen (H2) fuel is being explored as an alternative to hydrocarbons in engines because its emissions are cleaner.
- Most laboratory combustion experiments are performed in open air, yet in most practical applications, one dimension is restricted. Therefore, we are using a quasi-2D, rectangular cell called a Hele-Shaw cell to better simulate real life combustion (see figure 1).
- Flame propagation in the Hele-Shaw is examined with varying combustible gas mixtures and the flames' speed and shape are measured.

What I Did In the Lab

Figure 2. Compressed gas cylinders, including the hydrogen (H2) fuel cylinder (front).

Figure 3. The window from LabView, where we control what happens in the Hele-Shaw cell.

Results and Analysis

- Fascinatingly, it was discovered that flames in lower molecular mass fuels (e.g. H2) burn at the same speed no matter the direction of propagation, whereas for higher molecular mass fuels (e.g. propane, methane), the upward-propagating flames burn faster. It is unclear why this happens.

How This Relates to My STEM Coursework

Being a part of this lab has exposed me to the world of research, which has both similarities and differences with my STEM coursework.

Similarities
- Learning through experimentation
- Scientific Method

Differences
- In a high school STEM class, the labs and coursework are carefully structured by the teacher, but in a research lab, it is up to the researchers to construct their own way of gaining knowledge.
- In a research lab, discoveries are made that push the frontiers of scientific knowledge. In high school, the STEM teachers are already familiar with the results of the labs they assign us.

Skills Learned

Engineering-Specific:
- LabView (run experiments)
- MatLab (analyze data)
- PCC (Phantom Camera Control)
- GasEQ
- Lab safety
- Basic mathematics relating to combustion
- Reading and analyzing scholarly articles

General Skills:
- Independent/creative problem-solving
- Microsoft Excel, PlotDigitizer
- Making a poster

Figure 4. The flame's average position within the cell in terms of the video's frame number. We use this graph to determine the speed of the flame during the quasi-steady stage.

Figure 5. Examples of flames we created. Notice large-scale instabilities with the upward propagating flame (left), while the downward propagating flame (right) is more flat with small-scale instabilities. Interestingly, they both burn at the same speed.

Figure 6. Using PlotDigitizer and Excel, I took the graph from Figure 3 and plotted it against the cell's pressure as a function of time. This helps us examine the effects of cell pressure on flame propagation speed.

Advice for Future SHINE Students

- Have an open mind
- Be enthusiastic about learning
- Don’t be afraid of challenges
- Respect everyone around you

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