IV IV – Dancing Flames

https://www.youtube.com/watch?v=W8SkHCdnTFo

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Figure 1: A still image of the video showing a flame pulse

Introduction

For the fourth Image Video project in the course of MCEN 5151 Flow Visualization, the team of Ben Carnicelli, Nathan Gallagher, Alex Kelling, and David Milner focused on using high speed cameras to capture the combustion of a thin film of fuel. This is done using camping fuel poured in as a thin film over a bowl of water. Using a high-speed camera would allow the team to visualize throughout it the flame development and decay leading to a better understanding of the physics involved.

The video can be video at: https://www.youtube.com/watch?v=W8SkHCdnTFo.

Flow Physics

Pulsating flame behaviors over liquid fuel sources is something that has been observed and researched (Manhou Li, 2017). The flame pulsates between diffusion combustion and premixed combustion. The premixed combustion phase is when the flame experiences a pulse of growth. The flame spreads quickly over an area of premixed gaseous and liquid fuel. This mixture is created when the pulse recedes and forces the circulation of gas phase fuel created by the temperature change. Manhou Li's research shows that higher temperatures lead to higher frequency of pulsation. This is seen in the video as the pulsating does not occur until a sufficient temperature has been reached as the fuel is heated over time. An analysis of the fame pulses, only made possible due to the high speed camera, show a frequency of roughly 5.58Hz.

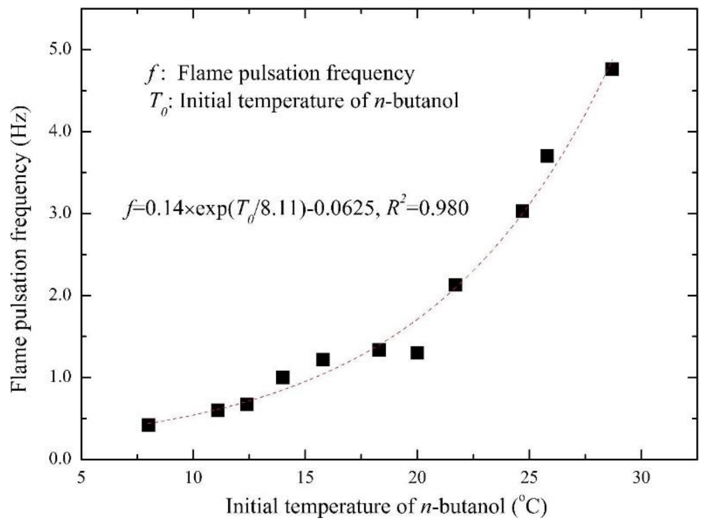

Figure 2: Li's analysis of temperature vs. pulse frequency

Video Time (VT) [VT sec]	VT indexed [VT sec]	Real Time [sec]	Time to Previous (TP) [sec]	Average TP [sec]	Frequency [HZ]
35	0	0		0.17917	**5.58140**
43	8	0.2	0.2		
50	15	0.375	0.175		
56	21	0.525	0.15		
62	27	0.675	0.15		
71	36	0.9	0.225		
78	43	1.075	0.175		

Figure 3: Calculation analysis of pulse frequency.

The analysis of pulse frequency was done by watching the video and recording the time when the pulse left the screen. The location of the pulse leaving the screen is not significant in itself, but serves as a consistent point to reference. The time was indexed off the first pulse and then converted to real time, knowing that the video was filmed at 1,200 frames per second, 40 times faster than it was played back at. The time between pulses is calculated and the frequency can be determined.

Experimental Set Up

To capture this video, a Phantom Miro C110 high speed camera was loaned from the University of Colorado, Boulder's Integrated Teaching and Learning Laboratory. This camera included a tripod and laptop with processing software allowing the team to set up, capture, and export the video quickly and efficiently. The camera was positioned nearly seven feet away from the subject, a bowl. The bowl was filled with water. A thin layer of camping fuel was poured on the top of the water. A thin film of fuel dispersed across the surface. A wet towel was placed underneath the bowl to limit the possibility of fire if any fuel had been spilled. Other safety precautions included team members ready to call for assistance, pour water, use the nearby fire extinguisher, with everyone keeping to a safe distance. Safety was held to the highest regard.

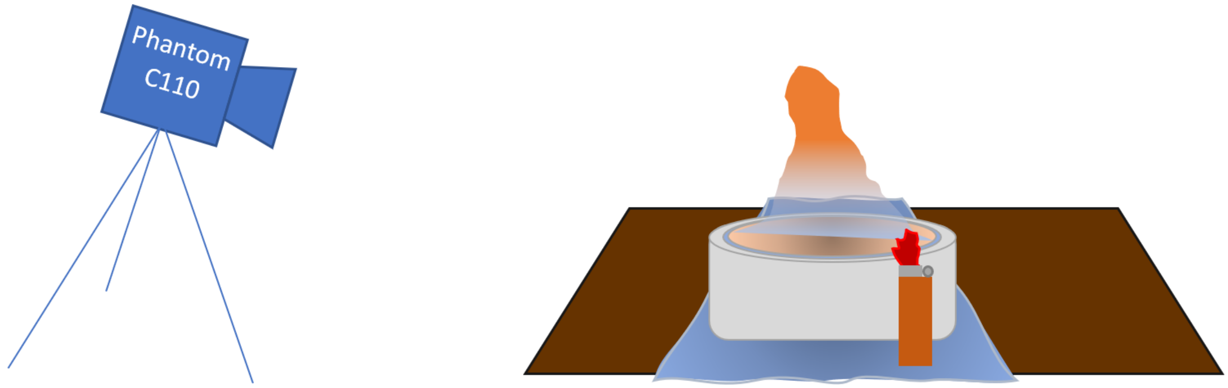

Figure 4: Experimental setup

One member of the team then took a lighter and slowly approached the subject. A quick touch of the lighter flame to the fuel created an ignition. Immediately a blue flame shoots across the fuel. As the initial combustion grows, an orange glowing flame rises and reaches upward across the bowl. The orange flame eventually settles as a larger flame in the center of the bowl with the edges reaching inward instead of up. One interesting phenomenon observed is the pulsing of the flame upward. After the development of the center flame, a periodic pulse of a large 'bulb' of a flame would gather and rise, leaving behind a thin shaft of flame. This would cycle as the fuel continued to burn. The video was left to the length captured by the trigger time. A playback time of 83 seconds is lengthy but allows an interesting look into ignition as well as the pulsating flame phenomenon.

Figure 5: The initial combustion

Photographic Technique

The camera used was a Phantom Miro C110 high speed camera. The Phantom is capable of 52,445 frames per second (fps) (Darwin Microfluidsics, 2022). A resolution of 1280x1024 is possible at a slower frame rate of 915fps. This video was filmed at 1,200 frames per second and is played back 40 times slower, at 30fps. The resolution for this frame rate is 1024x768. The metadata of the photo file did not include any information on the aperture, exposure, focal length, or ISO.

Editing this video was done with Microsoft ClipChamp. The video was cropped and resized to a square of 1920x1080. The introduction credits were added to give acknowledgements. Royalty free sound effects were added from the website pixabay.com. This included a first 'whoosh' noise when the first blue flame is racing across the surface of the unlit oil. A second 'swoosh' was added when the blue flame culminates into an orange flame tower when all the initial fuel has been lit. This was done to add intensity and a little bit of comedy to the video. The video of was uploaded for viewing on YouTube at https://www.youtube.com/watch?v=W8SkHCdnTFo.

Conclusion

This video went beyond the objective of capturing fire and combustion in slow motion. It educated the group members on a fluid phenomenon, pulsating flames, that can only be properly seen when using a high-speed camera. This video successfully detailed this phenomenon enough to give an introductory understanding of that is happening.

Bibliography

Darwin Microfluidsics. (2022, 11 6). *Phantom Imaging*. Retrieved from PHANTOM Miro C110 High-Speed Camera: https://darwin-microfluidics.com/products/phantom-miro-c110-high-speed-camera?variant=37445731680420

Manhou Li, S. L. (2017). Pulsating behaviors of flame spread across n-butanol fuel surface. *Applied Thermal Engineering*, *112*, 1445-1451. Retrieved from https://doi.org/10.1016/j.applthermaleng.2016.10.001