THE UNIVERSITY OF COLORADO

Group Image 2 Report

High Speed Video of Welding Torch Ignition

Christopher Francklyn

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Flow Visualization

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1. Purpose of Image

The image for this report was captured for the second group assignment for The University of Colorado, Boulder's MCEN 4151: Flow Visualization course. The class is designed to encompass multiple disciplines ranging from engineers to visual arts students. For this group assignment, students were asked to observe a fluid phenomenon of interest and document it through whatever visual medium he or she thought best represented the fluid flow. For this image submission, the group decided to observe the fluid phenomena that occur when a welding torch is ignited via a handheld sparking device. This was visualized through both still photos and high speed film taken at 3000 frames per second.

2. Image Set Up and Approach

The video was captured within the welding stations of the physics department manufacturing center. A standard flame welding torch was used to produce the combustion in the image. A hand held torch was placed and supported against a brick on top of one of the welding stations. The torch was held in place by an operator wearing a leather welding glove for safety. The Olympus I Speed high speed camera was fixed to a tripod mounted approximately two feet from the profile of the flame. The lens of the camera was on the same plane as the path of the flame. The control console – which was plugged into the back of the camera – rested in the lap of a second operator several feet away. This can all be seen in the schematic below.

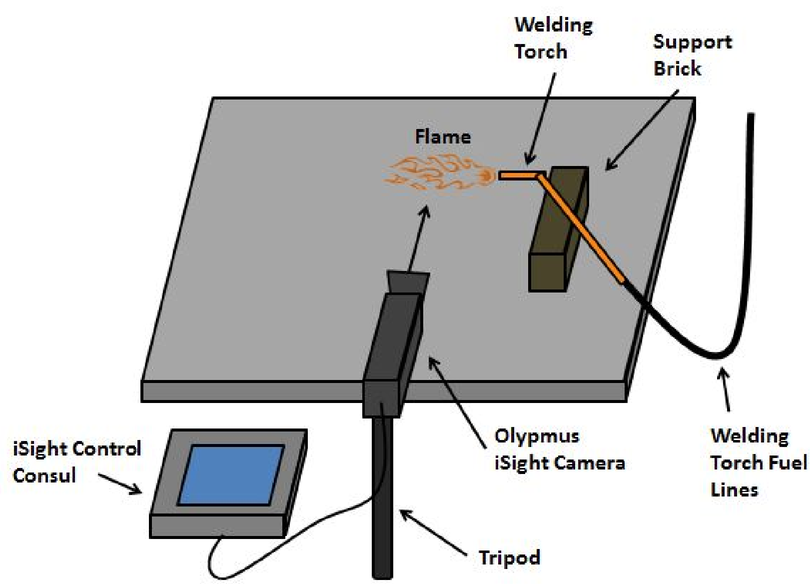

Figure 1: Experimental Setup for Welding Torch

To obtain each image, the operator running the control console set the desired capture frame rate and began filming video. The operator running the welding torch than activated the welding torch fuel line and sparked a hand held sparking device approximately 4 inches from the nozzle of the flame. The flame would light from the sparking device towards the nozzle of the torch. This would then be followed by the visible expansion and combustion of fuel in the direction of fuel flow (opposite the ignition direction). This can be clearly seen in the video sequences by the blue ring traveling from the sparks towards the nozzle prior to visible ignition. The flame was allowed to burn for several seconds, and then video capture was stopped on the control console. The goal of each video was to ensure proper positioning, focus, and detail of the flame, and to ensure that the ignition sequence was captured in a unique and informative way. Several different orientations of the support brick and welding torch were used to obtain different visualizations of the ignition sequence.

3. The Physics behind the Flow

In this experiment, an oxyacetylene welding torch was used. These welding torches combine both oxygen and fuel gas to weld and or cut a given material. In general, pure oxygen is used instead of generic air because the presence of pure oxygen drastically increases the flame temperature. Most welding torches use acetylene as their fuel. Acetylene torches typically burn around 6330°F. Prior to ignition, the operator opened both the fuel (acetylene) and oxygen lines. He then held the sparking device approximately two to three inches from the nozzle and scraped the sparking device to generate a spark. This spark then lit the fuel/oxygen mixture, which sent a small blue ignition flame towards the source of the fuel. Once this small blue flame reached the correct concentration of oxygen and fuel, it caused uniform combustion of the fuel and oxygen, which then propagated in the direction of fuel flow – ie away from the welding torch.

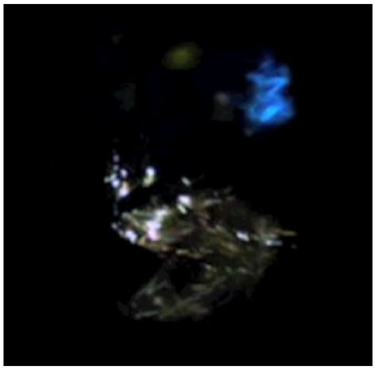

Figure 2: Leading Flame (Blue) and Sparks (White Flecks)

One of the interesting parameters that can be calculated from the high speed footage is the time it takes the welding torch to fully ignite. When seen in real time, the human eye is unable to notice or discern the nuances within the flame lighting, or the time it takes to reach full ignition. It generally appears as though a spark is generated, and then the flame appears. When the footage is slowed down and analyzed on a frame by frame basis, one can calculate the time it takes to ignite, and the speed at which the flame is traveling just prior to full ignition. In order to do this, one only needs to know the frame rate that the footage was shot at, and be able to step through the footage at a frame by frame basis. The following two images were captured at the onset of flame formation, and at the point at which the flame reached peak extension.

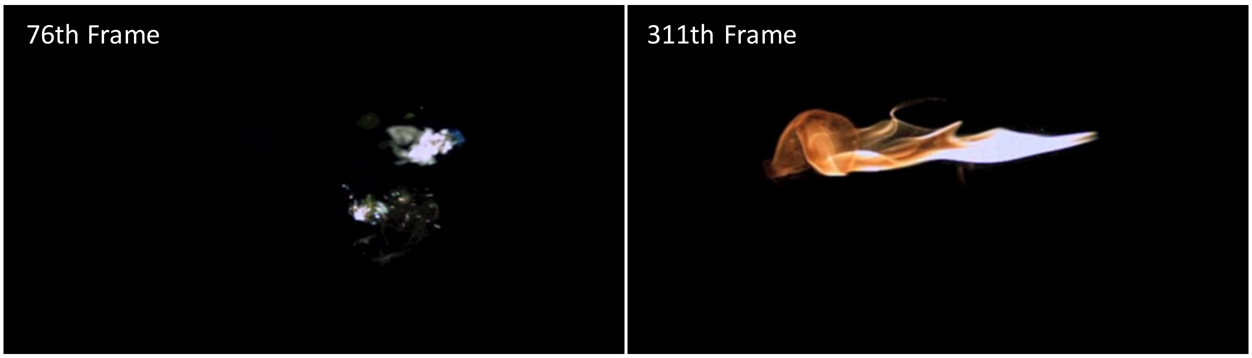

Figure 3: Flame Onset (Left), Final Extension (Right)

Since the frame rate that the above footage was captured at is known, the total time for ignition can readily be calculated:

$$Known\ Frame\ Rate = \frac{3000\ Frames}{1\ second}$$

$$Calculated\ Ignition\ Rate = \frac{Frames\ per\ Distance\ Travelled}{Time\ per\ Distance\ Travelled} = \frac{235\ Frames}{x\ second}$$

$$Calculated\ Ignition\ Rate = Known\ Frame\ Rate\ \therefore \frac{235\ Frames}{x\ second} = \frac{3000\ Frames}{1\ second}$$

$$Calculated\ Ignition\ Time = \frac{235\ Frames}{3000\ Frames}(1\ second) = \mathbf{0.0783\ Seconds}$$

This calculation shows that the time for the flame to fully ignite is approximately one tenth of a second, which is difficult to discern by the human eye. Another useful metric that can be easily calculated is the rate at which the flame is expanding. Since the time required for the flame to fully extend has already been calculated, and the distance that the flame travels is known, the speed of the flame at full extension can be calculated.

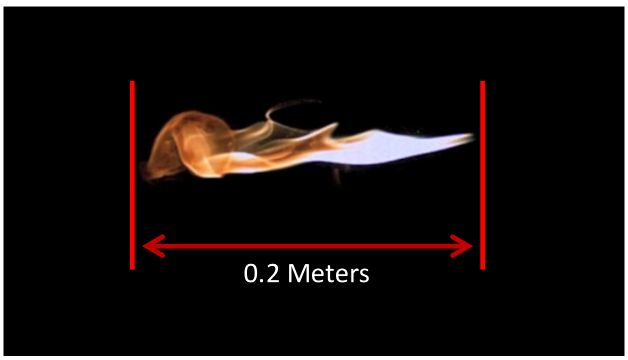

Figure 4: Extended Flame with Scale

$$Flame\ Length = 0.2\ Meters$$

$$Calculated\ Ignition\ Time = 0.0783\ Seconds$$

$$Flame\ Speed = \frac{Flame\ Length}{Ignition\ Time} = \frac{0.2\ Meters}{0.0783\ Seconds} = \mathbf{2.55}\ \frac{\mathbf{Meters}}{\mathbf{Second}}$$

This calculation shoes that the flame travels at a velocity of two and a half meters a second. In another unit scale, this means that if the fuel and properties of the flame would allow it, the flame would travel one and a half times your average male in once second.

4. Visualization Technique

The video was taken using an Olympus I-Speed High speed video system. Each video series was taken at a given frame rate (typically around 3000 frames per second). The camera is composed of a filming unit, a short term flash memory, a hard drive card memory, and a control unit. Each video sequence was captured onto the short term flash memory of the control unit. A start and end point for the desired length of video was then chosen. This section of video was then rendered and transferred to the removable memory card storage unit. The camera was only capable of retaining one video series in its short term memory, so each video sequence had to be cut to length and rendered before another video could be captured.

One of the short comings of the high speed camera is its requirements for bright lighting. The sensitivity and resolution of the camera are both relatively low and both only decrease as the desired frame rate was increased. This meant that if more frames were desired – producing a more fluid high speed sequence – the frames per second value had to be increased. Each time the frame rate was increased, the footage brightness decreased drastically. Typically, this decrease in recorded ambient light is offset through the use of bright stand lamps. However, the generation of the frame was bright enough in the darkly lit welding room to provide ample light for video capture. Additionally, as the frame rate was increased, the recorded image was zoomed in. This is a result of the sensor using less of its surface area in order to better maximize its capture of available light.

Another factor which played a role in the number of videos that were obtained was the time each video took to preprocess. After being captured, the user had to enter the video editing menu of the control unit and manually pick a start and end point for each video. The video was then rendered to the removable 4 GB memory card. Depending on the real time length of each video and the frame rate it was shot at, this process could take upwards of ten minutes per sequence. Each video also had to be correctly framed prior to capture. This was a difficult process as the control unit screen was almost completely black without the presence of the welding torch to provide light. To remedy this, each video was framed with the frame rate set at an extremely low value. Once the camera was positioned correctly with the path of the torch filling the shot, the frame rate was increased to the desired level.

5. Photographic Technique

The video was produced using iMovie on a Mac desktop. Each image had to initially be converted from an .avi file type to a .mp4 format, which is able to be read by iMovie. To do this, a free video converting software was used. It took a while for one to be found which did not leave a distracting water mark in the middle of the image, and the resulting program may have lowered the quality and resolution of the video after it was processed. The overall intent of the video was to show the unique flow patterns that exist as the high speed footage was played in a non-traditional orientation – namely in reverse. Different footage was shown playing slowly in the advancing direction, and was timed with the synced music to rapidly reverse as the flame reached the apex of its flow path. This reverse viewing gave the footage a unique feel and allowed it to be visualized in a non-standard manner.

6. Conclusion

Overall this image nicely captured and portrayed the formation of a flame in a unique manner. The use of high speed video allowed for approximately 0.5 seconds of action to be slowed down to approximately 15 seconds of detailed footage. The intricacies of the random, chaotic nature of the flame were clearly visible at such a high frame rate. While the video footage could have been better in focus or of a higher resolution, the movie still creatively shows the desired flow effect.

Works Cited

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