Austin Ramirez

Collaborators: Julian Cruz, Jon Cohen, Saud Alobaidan

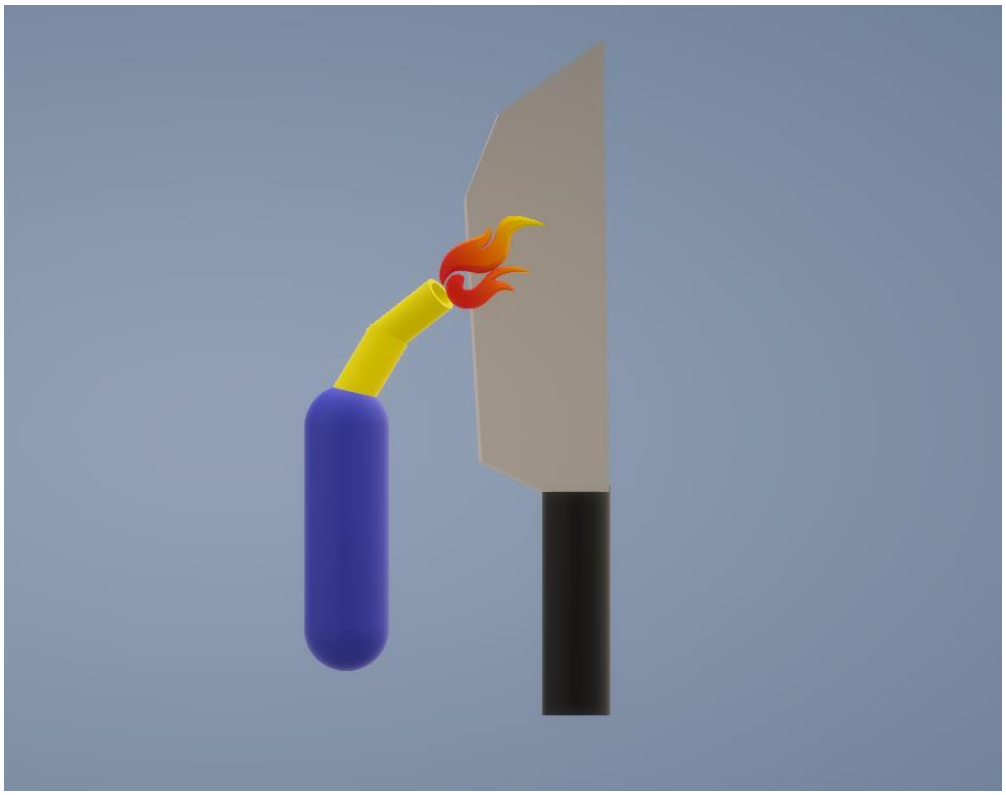
Team Second Report

11/11/19

https://youtu.be/nrSyLJmnKzg

The video that is to be analyzed in this report was taken for the second team photography assignment of the flow visualization course. The video was captured with the intent of showing how a jet of ignited propane acts when it impinges on a surface. There are interesting fluid mechanics that occur when a jet impinges on a surface and these mechanics occur as a result of many factors from the angle of the jet to the geometry of the nozzle. The video was taken by my teammates in slow motion to better analyze the flow.

The flow apparatus (seen below) was very simple. It included a propane torch with a standard nozzle with the jet of propane coming out of the end directed at the surface of a knife. The angle at which the knife was positioned with respect to the jet was adjusted to a rather low angle so that the fluid mechanics could be better analyzed. The illumination of the photo was done by the torch itself and in post processing, the contrast was further increased to decrease the presence of any surrounding light.



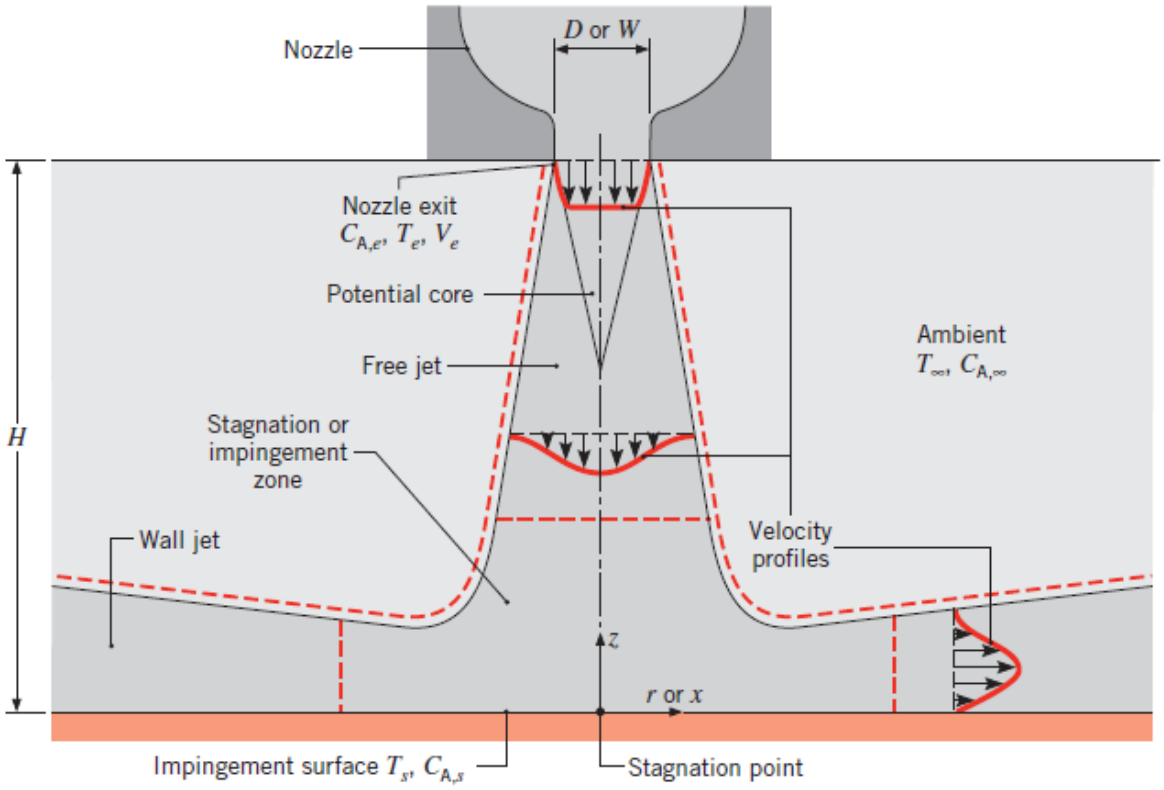
This apparatus allowed for the fluid mechanics of an impinging jet at a low angle to be observed. It is difficult to approximate the Reynolds number of the flow itself, but it can be all estimated to be laminar. Seeing as the viscosity of propane is 22.53×10^{-6} N-s/m^2, the density is 0.54 kg/m^3, and the length of the blade on which the jet is impinging is 0.02 m, the velocity of the flame would have to be greater than 1043 m/s in order to be turbulent, which, for a jet coming from a propane torch, is a very high fluid velocity. Additionally, these nozzles are usually engineered in order to create proper jets which tend to be laminar in nature.

$$Re = \frac{\rho v L}{\mu}$$

$$5 * 10^5 < \frac{0.54 * v * 0.02}{22.53 * 10^6}$$

$$v > 1043\ m/s$$

The impingement of the jet can be observed in the video and the fluid mechanics of this jet can be seen below in the diagram which shows the boundary layers, velocity profiles and different zones of the impinging jet system.



The visualization technique used here used the illumination of burning carbon to show the direction of the flow. The torch used was a Bernzomatic propane torch with a nozzle that gave off three different paths for the propane to flow through. This can be seen in the video as there are three distinct flames of brighter color than the rest of the flame. The reaction that occurred to make this flame was of the propane reacting with oxygen as seen here:

$$C_3H_8 + 5O_2 \rightarrow 4H_2O + 3CO_2$$

This equation does assume complete combustion, which is the bulk of the reactions happening between molecules of oxygen and propane, however, incomplete combustion does occur, forming carbon monoxide and molecules of carbon, becoming soot. The lighting for the video was from the light emitted by the propane flame, which was turned up enough to show impingement but not so far as to use up all of the surrounding oxygen too fast and go out as it would if the flame was too close to the knife or too powerful.

The field of view on the video was rather small. It was at most 10 inches x 10 inches as the distance from the camera to the image was only about 12 inches. The camera used was that of an iPhone XR which was shooting slow motion video at 240 frames per second in 720p quality. This allowed for the smaller details to be seen in the inconsistency of the jet and in the path of the jet itself once it impinged on the blade. Once the video was captured, some slight post processing was done on the image in order to increase the contrast to better focus on the flame rather than the surroundings and also try to decrease some of the image noise in the video.

This image helped to reveal how jet impingement looks, using just common items. Unfortunately, the video quality was not as good as intended and it was difficult to see exactly what was happening and, in my opinion, there was a lot of potential that may have been missed out on here in terms of visualizing an impinging propane jet. In order to further develop this idea, I would ideally like to create a propane jet that is more powerful and visible, so that the surface on which it impinges can be father away. Additionally, taking photos and videos from different angles of this mechanic would be very interesting, and more possible with a larger jet.

Bergman, T. L., Lavine, A. S., Incropera, F. P., & DeWitt, D. P. (2015). Fundamentals of heat and mass transfer, 2011. In *USA: John Wiley & Sons. ISBN*.