IV-3 Report

Hydraulic Jump

MCEN 4151 - Joel Carlson 11/30/2021

I. Experiment Purpose

For this experiment, the purpose was to examine the phenomena known as a hydraulic jump. The motivation of this experiment was actually inspired by my civil engineering roommate who was learning about hydraulic jumps and telling me about them. The goal was to simulate a hydraulic jump and create a high quality photo of the effect.

III. Experimental Setup

For this experiment I used an empty Gatorade bottle and cut two holes in it. The first hole was located on the bottom of the bottle and had an area of about $1 cm^2$. This hole was to let air in as water drained from the bottle. The second hole was in the lid of the Gatorade bottle. In order to acquire a more uniform and laminar flow, I used a $\frac{5}{16}$ inch drill bit to make this hole. The bottle was filled with water and then poured into a large 30 centimeter stainless steel saucepan from a height of around 10 to 15 centimeters. A diagram of the setup can be seen below in *Figure 1*.

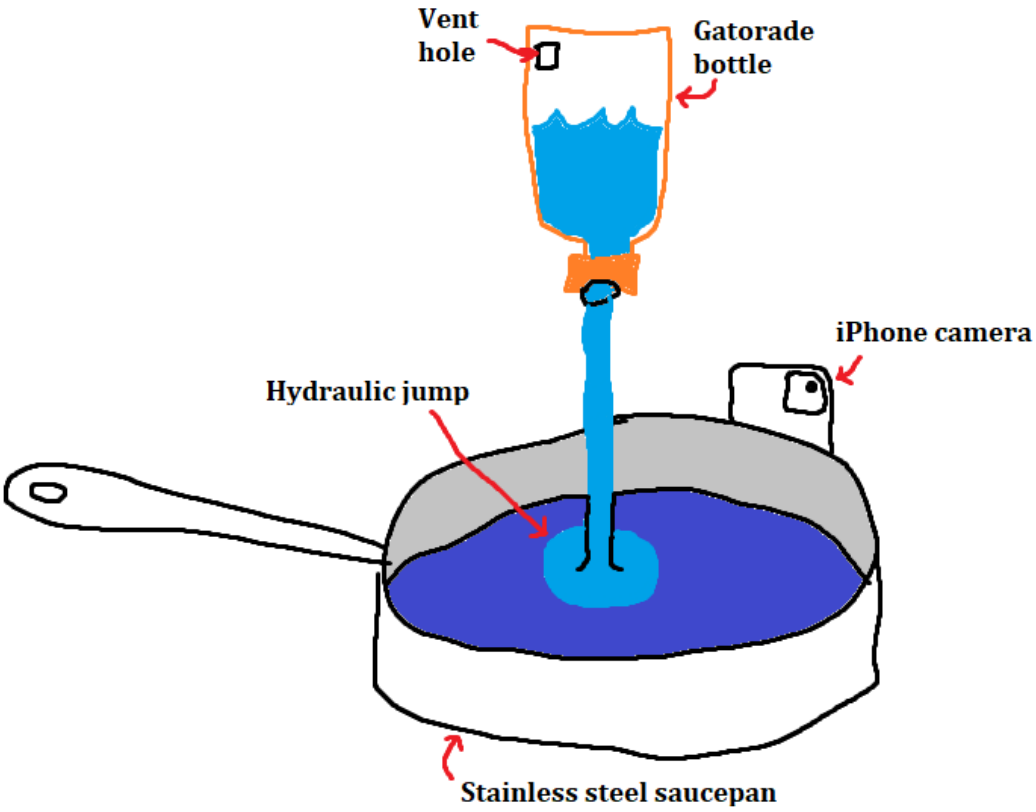


Figure 1: Experimental Setup Diagram

While pouring I used an iPhone 12 to take around 30 pictures of the effect. The experiment was repeated 3 times. In between experiments I changed the camera position and angle. In the end I had around 100 photos and chose my favorite.

III. The Fluid Mechanics

A hydraulic jump occurs when a liquid of high velocity transitions into a zone of liquid at a lower velocity. A diagram of a circular hydraulic jump can be seen in *Figure 2.*

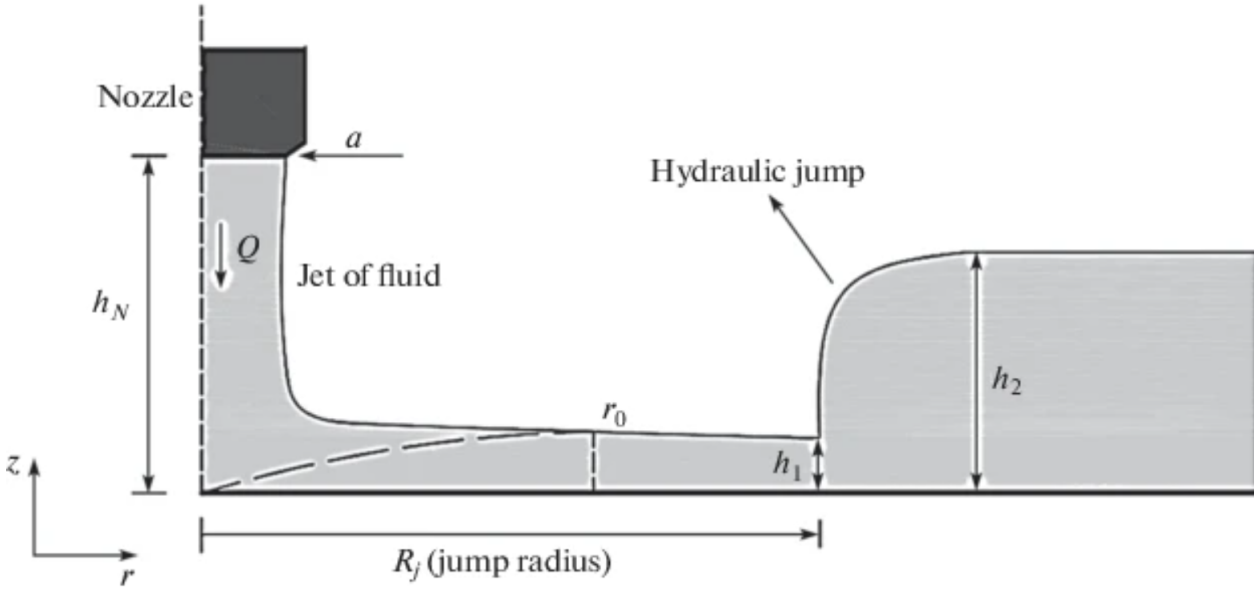


Figure 2: Hydraulic Jump Diagram [1]

The equation to describe a circular hydraulic jump can be seen in *Equation 1*.

$$\frac{R_j h_2^2 g a^2}{Q^2}\left(1+\frac{2}{Bo}\right)+\frac{a^2}{2\pi^2 R_j h_2}=r_0$$

Equation 1: The equation used for predicting the radius of circular hydraulic jump [1]

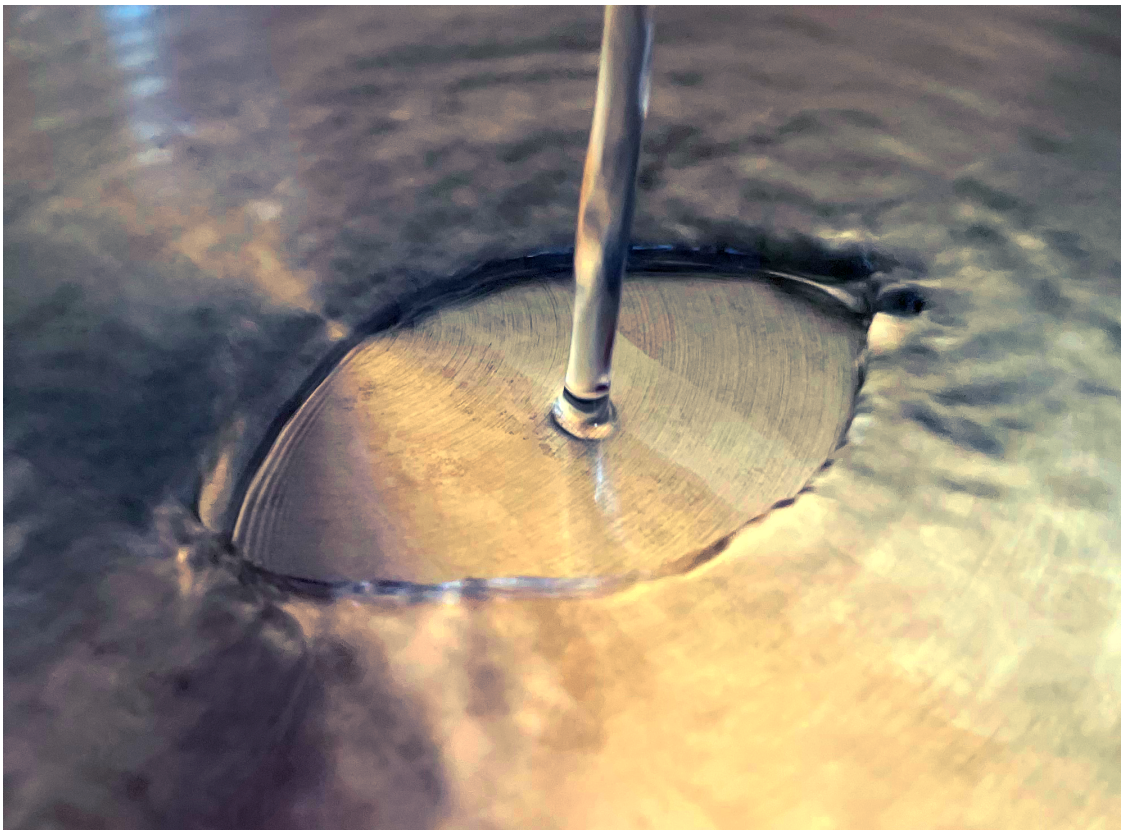
Here, R_j is the jump radius, r_0 is the radius when the boundary layer reaches the flow surface, h_2 is the height of the jump, g is gravitational acceleration, a is the jetty nozzle radius, Q is volumetric flow rate, Re is the Reynolds number of the fluid, and Bo is the Bond number [1]. Unfortunately, due to me not taking measurements during my experiment or having a steady state situation, I can not use this equation on my own experiment for validation. In addition, my hydraulic jump profile was not circular; I think this may be due to not having a perfectly circular jet of fluid. However, apparently this can also happen when the liquid has a higher viscosity than water and is known as a "cat's eye jump" [2].

IV. Photographic Technique

An iPhone 12 Camera was used to capture the experiment. The camera was held about 15

centimeters away from the object. The picture was taken in the daytime with my blinds open to let in sunlight. The original image was 3024 x 4032 pixels. The exposure time was $\frac{1}{121}$ seconds and aperture was maxed. The post processing was done in GIMP and involved adjusting the exposure, contrast, brightness, colors, and using GIMP's auto white balance.

The Original Image above



The Final Image above

V. Image Remarks

I think this is my favorite photo I have taken for the class. The shape created is extremely fascinating to me and in addition I thought the post processing turned out really well and highlighted some of the colors in the image. Aside from the shape of the jump, my favorite part of the image is the perfectly smooth, mirror finish of the high velocity water leading to the jump. I really like that you can clearly see the texture of the pan beneath, I think this adds a lot to the image. I honestly don't think I would change anything if I were to repeat this experiment. I also think whatever imperfections led to the creation of the "eye" shape was purely luck and may be difficult to reproduce.

VI. References

[1] Asadi, A., Jafarian, S. & Teymourtash, A. Experimental Study of Stable

Circular Hydraulic Jumps. *Fluid Dyn* 55, 477–487 (2020). https://doi.org/10.1134/S0015462820040035

[2] Aristoff, Jeff, and John Bush. “National Science Foundation - Where Discoveries Begin.” *NSF*, 14 Dec. 2009, https://www.nsf.gov/news/mmg/mmg_disp.jsp?med_id=66053&from=mmg.