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Group Project 1: Bouncing Jet

Flow Visualization

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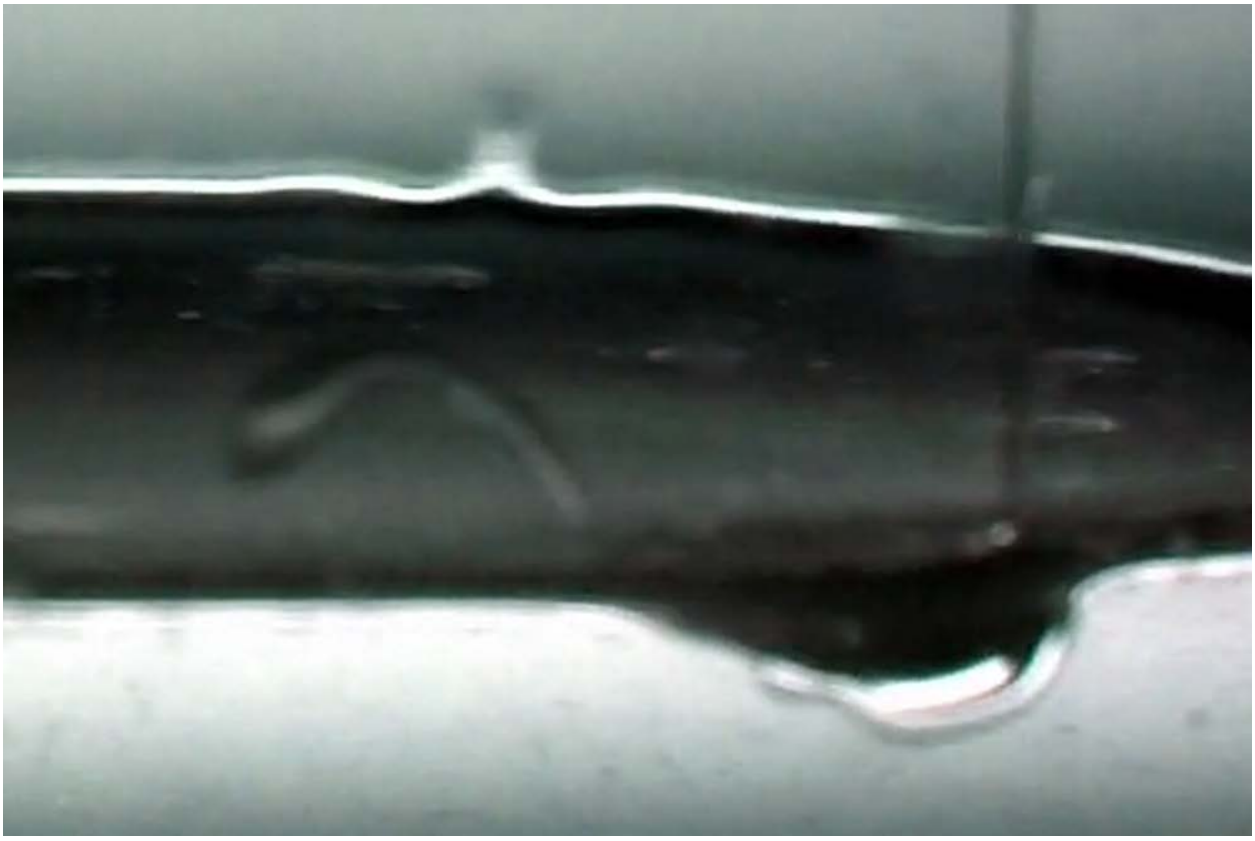

This video was the first attempt at group number seven to capture an image together. As a whole the group decided to try capture an image of the bouncing jet of Newtonian fluid. As the project developed, the group opted to capture a video of the phenomena as the jet would not last for very long and capturing still images proved to be somewhat challenging. Even still the resulting video clip was fraught with challenges.

The experimental apparatus was relatively simple. The fluid used was common mineral oil. A small bath of the oil was contained in a clear Lucite tube approximately ten centimeters in outer diameter which rested on a record turntable as is shown in figure 1. The mineral oil bath was centered on the turntable to create an even rotation of the oil bath. The stream was created by placing another small amount of mineral oil in a plastic bottle with a small orifice pierced through the cap. The orifice was approximately two millimeters in diameter. The mineral oil was forced from the bottle, through the orifice, and vertically down into the bath as the bath was slowly rotating. This was done by hand as to how much force and at what height the jet was starting at, but usually with practically no outside force, and about five centimeters from the surface of the rotating oil bath. Occasionally, the stream was perturbed using a small plastic rod, about five millimeters in diameter. It was passed back and forth through the jet to incite the air bubble between the stream and the oil bath.

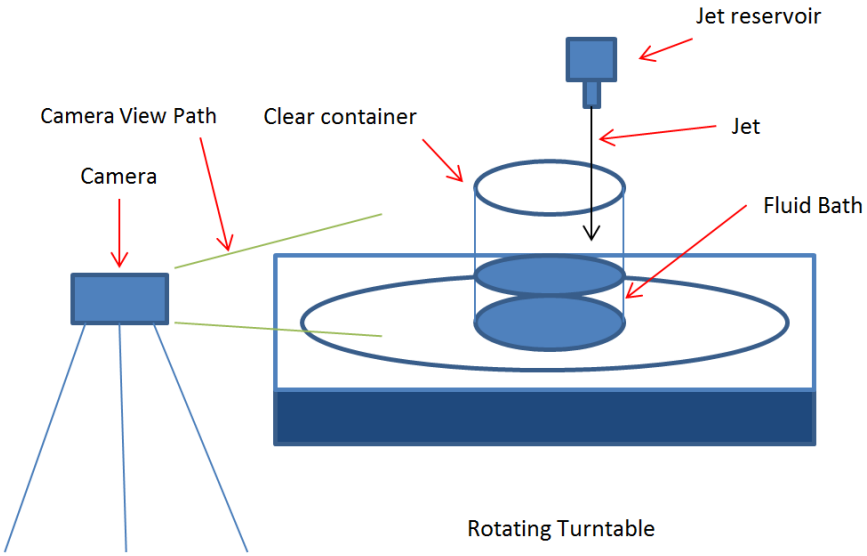

Figure 1: Experimental Apparatus

The bouncing jet is a curious phenomenon that occurs in Newtonian fluids. A close cousin to this effect is the Kaye effect, which is seen in Non-Newtonian fluids, such as shampoo, but studies have shown that this is a slightly different effect than the bouncing jet [1]. The bouncing jet is a non-coalescence effect, and occurs in much less viscous fluids than the Kaye effect. As the jet is forced from the bottle into the bath, a small air pocket is formed as the jet

tries to penetrate the bath. This entrained air pocket, coupled with the horizontal motion of the bath will tend to force the jet up and back out of the fluid, causing the bouncing effect of the jet [1]. The process is sketched in Figure 2. By varying both the rotational speed, and the jet velocity and flow rate, some dramatic bouncing jets can be created.

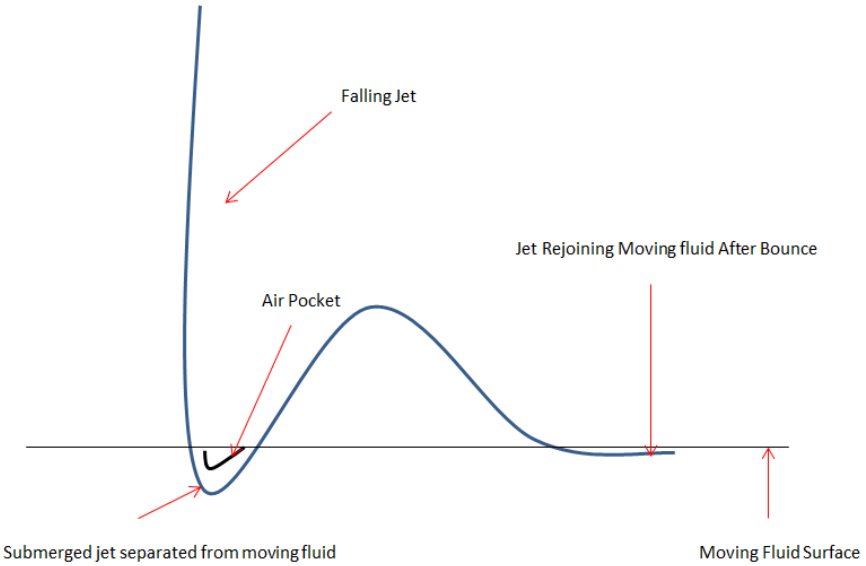

Figure 2: Bouncing Jet

The mineral oil itself is commonly available at drugstores and supermarkets. It has a specific gravity of between 0.76 to 0.87, and viscosity of less than 34.5 centistokes at room temperature [2]. Given that the orifice was about two millimeters, and an estimated velocity of 0.6 meters per second due to the fall height, the Reynolds number would be about 34.8. This placed the flow clearly in the laminar regime. The equation for the Reynolds number is given in figure 2. The turntable was set to spin at 33 revolutions per minute. Given the outer diameter of the bath is ten centimeters; the fluid bath had a velocity of 17.3 centimeters per second.

$$Re = (V*L)/\upsilon = [(0.6\ m/s)*(0.02\ m)]/\ (3.45 \times 10^{-5}\ m^2/s) = 34.8$$

Figure 3: Reynolds Number calculation

The visualization techniques were interesting to say the least. There was no dye added to the mineral oil, as it caused undesirable effects to the viscous characteristics of the oil, and made jet creation more difficult. It is a naturally clear, colorless, and odorless liquid, so it remained that way for the experiment. The velocities that were added via the turntable and jet

flow were the only alterations made to the fluid. It was also undiluted. Mineral oil is available off the shelf at most grocery stores and pharmacies as an intestinal lubricant. The only other modification to the experiment was the lighting. The oil was lit both from the front and the back by fluorescent tubes, as well as halogen lamps each at about 18" distance from the bath. There were 2 halogen flood lamps rated at 500 Watts each. There were also 2 fluorescent tubes, rated at 32 Watts each. There were also general indoor fluorescent room lights overhead. There was a white back board behind the turntable to avoid other background distractions during the shoot.

The photographic technique used was quite simple. The camera used was a FlipVideo brand high definition Flip camera. It is capable of shooting videos at 720p resolution. The camera shoots at 60 frames per second, and uses H.240 video compression. The resolution is 1280 pixels wide by 720 pixels in height. There is no ISO information provided by the manufacturer of the Flip camera. There are few adjustable settings on the Flip Camera itself. There was also a 35mm macro lens attached to the body of the camera for some added magnification of the image. The camera was mounted on a tripod oriented 12" – 14" from the fluid bath on the turntable. It was also about one inch higher than the surface of the oil bath in order to have a slight downward perspective on the jets. As far as post processing, there was a decent amount done to this video to try to bring out the best visualization of the bouncing jet. It was difficult to get it to last for an appreciable time, as well as get appropriate lighting on the jets when they did occur. First, the speed of the video was brought to 20% of its original. The video was cropped to focus in on the area where the jet was manifesting itself. The brightness, contrast, and gamma factor were all manipulated to try accentuating the jet when it occurred. Finally, the hue was altered to give a bit of a green tone, just to make it a bit more visually appealing. Not pertaining to the video itself, a short music track was overlaid, to try to match the sequence of events in the video for added dramatic effect.

This video shows the bouncing jet on a free surface of Newtonian liquid. It was interesting to see and capture the phenomenon, but the experiment was plagued by difficulties. The lighting could not be satisfactorily supplied. The nuances of creating this fluid flow were much more tedious than previously expected. There were many factors in creating the flow that could have been much more stringently and scientifically controlled, such as rotational speed, jet diameter, and flow rate. With more practice and variability in the different parameters this video could have been shot at a much higher quality. The flow intended was shown, but not as well as was hoped. The music choice seems to have been somewhat controversial after the critique reviews, but that is something that is more of a personal opinion, and not really related to the fluid flow. Overall, this was a very interesting fluid flow to capture, and although it could be (and has been) done better. It was a successful video capturing the bouncing jet.

References:

[1] Matthew Thrasher, Sunghwan Jung, Yee Kwong Pang, Chih-Piao Chuu, and Harry L. Swinney, "Bouncing Jet: A Newtonian Liquid Bouncing Off a Free Surface" Physical Review E 76, 056319 (2007)

[2] http://home.fnal.gov/~randy/tech_specs.html

[3] http://en.wikipedia.org/wiki/Flip_Video