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"Get Wet" Summary Report

Flow Visualization

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As a first attempt at capturing fluid flow phenomenon in an image, this concept was a try at recreating an inverse jet or fountain of oil into water. This image was initially thought to be yet another exploration in to the classic oil versus water concept with a twist of the dichotomy of the densities interplaying as they mix. It has been done many times before, but this image was an effort in trying to reinvent this scenario in an original sense. The oil was particularly dense and it was thought to be an attempt at an inverse jet or fountain protruding into the water before breaking apart into the oil droplets and rising to the surface. Once the droplets reached the surface of the water, they only survived for a short amount of time before bursting and settling into a thin layer at the surface of the water. The purple color of the oil is intrinsic to the brand of oil, and the water is its naturally clear color, so the post production of the image as far as hues and colors are concerned is quite limited. There was some accentuation of the background whiteness done, due to the inadequate lighting of the original image, but that is about it as far as post production of the image is concerned.

For the image the artistic goal was to capture the age old battle of water in oil. In this case the battle of the forces of gravity on the falling oil through air, into a tub of water, and then the buoyant forces of the oil counteracting the forces from the fall into the water and bringing the oil to the surface of the water again. The actual flow apparatus was relatively simple. It was a small clear plastic tub, free of obvious surface defects. The dimensions of the tub were six inches deep, six inches in height, and sixteen inches wide. The apparatus can be seen as a labeled sketch in figure 1. The oil was poured in a thin stream of approximately one to two millimeters in diameter from about six inches above the surface of the water. The oil would penetrate approximately two to three inches into the water before breaking into the droplets and rising back to the surface. The water was plain tap water. The falling oil would remain as a stream for a short period of time before the oil instability in the water broke it apart into small droplets as it rose to the surface. Once the oil sat at the surface of the water in small droplets, it would contact other droplets. Then the surface tension of the oil droplets would break and the oil would combine to form a smooth film on top of the surface of the water due to its density and immiscible nature with water.

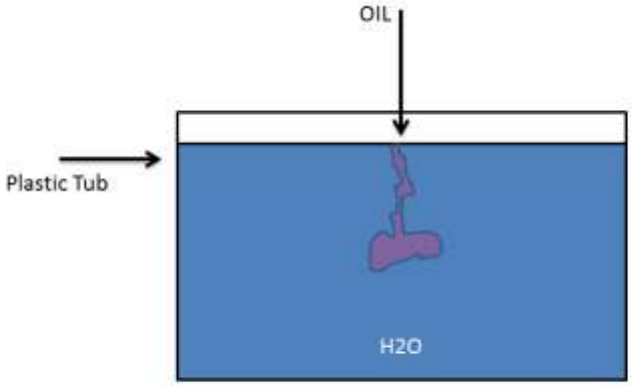

Figure 1: Flow Visualization Apparatus

As the water was entering the water the Reynolds Number was estimated and the calculation is shown in figure 2. This dimensionless number is essentially the ratio of the inertial forces of the fluid and the viscous forces of the fluid [1]. In this calculation the mean velocity of the oil entering the water at the surface was estimated to be 4.9 m/s due to the height it was falling from under the force of gravity and the approximate time it took to fall that distance. The linear dimension was estimated to be three inches as stated before, or 0.0762 meters. The kinematic viscosity of the oil was found on the manufacturer's website for the particular oil type and weight, this value was found to be listed as 76 Centistokes, or 7.60×10^{-5} m^2/s. The Reynolds number found is 4913; this would put the flow into the turbulent regime generally speaking, as we learned in fluid mechanics class. The flow exhibited some turbulent behavior before breaking apart into droplets, but this is also most likely due to the buoyancy of the oil entering into the water. The jet of oil as it entered the water exhibits Rayleigh-Taylor instability, which is the behavior of fluids of differing densities interfacing [2]. Since the fluids are also immiscible, as the instability occurs, the oil separates into small droplets. Once the droplets a numerous enough, and small enough, the mixture becomes an emulsion. Since the oil is dropped from a height above the surface of the water in a thin stream is essentially behaves as a jet upon entering the water, before the RT instability occurs. The force of the jet is essentially created by gravity alone. The momentum is then transferred from the jet of oil into the water, thereby causing the rapid deceleration and decomposition of the jet [3].

$$Re = (V*L)/\upsilon = [(4.9\ m/s)*(0.0762\ m)]/\ (7.60 \times 10^{-5}\ m^2/s) = 4913$$

Figure 2: Reynolds Number calculation

The techniques and materials used to create this image were discussed briefly earlier, but a more complete explanation should be offered. The oil used in creating this image is a brand called Royal Purple. They specialize in high performance and racing motorsports oils and lubricants. This particular oil was a 10w-30 weight engine break in oil. It has a listed density of 859 Kg/m^3 [4]. And, as their name would suggest, the oil comes from the manufacturer dyed to a deep purple color, so no additional dyes or additives needed to be used. The water was just plain city tap water contained in a clear plastic container. All of the elements in the image were at ambient temperature during the time of shooting the image, or about 65 degrees Fahrenheit. Also, all of the oil was disposed of properly at an authorized motor oil recycling center. The lighting was achieved from a pair of 500W industrial halogen flood lamps, placed to the right and rear of the camera, about 1.5 meters away from the flow. There was no flash used on the camera, as it was causing undesirable glare on the plastic container itself,

preventing proper imaging of the flow. The background was just plain white paper, so there were no distractions from the flow itself.

The photographic techniques used were not all that exotic either. The camera was a Sony DSLR-A230. The lens was a Sony SAL-1855 zoom lens. It was placed on a small tripod approximately six to eight inches in height to align it with where the flow was intended to occur. The camera was also placed approximately eight to ten inches away from where the flow was intended to occur to gain proper focus. The image as taken is 3104 pixels in width, and 1664 pixels in height, and both the horizontal and vertical resolutions were 240 dpi. The camera settings used for the image were an F-stop of f/5.6, the exposure time was 1/100 seconds, the ISO speed was also ISO-100, and the focal length was 20mm. The maximum aperture was 3.61. The size of the file created for the image was 14.8 MB. These settings were chosen mainly because they were capturing the flow in the clearest manner given the lighting and flow apparatus setup. The goal was to try to get the best natural image of the flow in order to reduce the need or desire for a lot of digital processing, after the fact, in Photoshop. That being said, there was a small amount of post processing that was done in Photoshop. The lighting from the flood lights was a bit more yellow and red in spectrum and heat than was desired, so the white balance was adjusted to brighten up the background. The image was cropped slightly to focus on the flow so there was less extraneous background in the image. The curve function was used to accentuate the image, with an input of 63, and an output of 139. Lastly, the fill function was used to remove some of the imperfections introduced by the plastic container. That was essentially all that was done in the post production process.

Overall, the image turned out to be quite a bit different than the original intention. This was mostly because of how the image of the flow turned out, not because of a failure at achieving the flow characteristics that were initially sought, but the presented image was more intriguing. The image presented turned out to be more visually pleasing than the original intended image idea. The idea of oil in water, both physically and metaphorically is classic imagery. The flow illustrated holds true to both of those concepts in that it demonstrated the immiscibility of oil in water in a visually interesting way. The stark color and lighting contrasts of the image bring out a lot of detail in the interaction of the two fluids. In a basic sense the intent of the image was achieved, but there could be more interesting experimentation to explore. There could be other experiments with differing oil weights and types, as well as changing the temperature of the oils and the water from hot to cold extremes to alter the viscosity of the oils. All of these things may alter the formation and development of the flow characteristics. For purely aesthetic and visual reasons there could be dyes or other additives included to alter the flow appearance, but overall the general flow physics of oil in water were demonstrated clearly in this image.

References:

[1] http://en.wikipedia.org/wiki/Reynolds_number

[2] http://en.wikipedia.org/wiki/Rayleigh%E2%80%93Taylor_instability

[3] http://ufdc.ufl.edu/UF00102023/00068

[4] http://www.royalpurple.com/products/#!hps-motor-oil