# TEAM THIRD IMAGE – COLLISION OF TWO VISCOUS STREAMS

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**ABSTRACT**

In this paper we shall look at how the use of a glycerin-water mixture was used in the capturing of the above image that resulted between the collision of two viscous flows. The overall desired result was to successfully capture the collision and resulting fluid thread breakup that occurs when two jets collide at relatively slow velocities. There were several conditions that improved the overall quality of the picture including the absent of wind or another intruding external force that would alter the fluid interaction as well as the use of diffused light in the background.

**Flow Visualization**

The use of dynamic motion in photographs has always been interesting to people. This could possibly be due to the fact that the inherent qualities of a still image of a flowing process lends to the imagination of the viewer in such a manner as to make him or her feel like the picture is moving. Flow visualization is the process of making the physics of fluid flows (gases, liquids) visible [1]. In this paper we will explore how a still image of the collision event between two semi viscous fluids.

**Glycerine**

Viscous fluids have a wide range of uses from lamp oil to dish soap to even honey. But outside of the consumer market the interaction of viscous fluids can be very important, with one such interaction being between the collision of two viscous fluids at high velocities. This is often present in the analysis of jet-on-jet impinging devices such as in propellant injectors for bipropellant rocket engines, various chemical reactors, and various liquid to liquid extractions [2]. Viscous fluids can be made from a large range of chemical, but for this piece we shall look at the combination of glycerin and water.

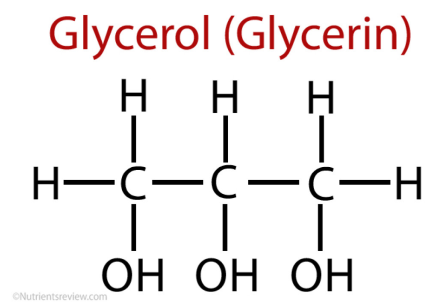


Figure 1: Glycerin Molecule

The molecule shown in Figure 1 is of the glycerine molecule also known as glycerol which is a three carbon alcohol that contains three hydroxyl groups [5]. The three hydroxyl groups, which are the three OH, can be identified as the main contributor for the solubility of the molecule. The glycerin molecule as shown above is clear, odorless, and colorless and it is typically in a syrupy like liquid form.

There are numerous commercial applications of this molecule which include but are not limited to the following: adhesives, sealants, fuel, fuel additives, lubricants, lubricant additives, paint additives, processing aids, and various solvents [4]. In addition to the industry uses there are an equal if not more number of consumer application that include: agricultural products (not pesticides), anti-freeze, deicing products, automotive care products, building materials, construction materials, cleaning supplies, explosive materials, food packaging, fuels, fuel related products, laundry and dishwashing products, garden products, paints, food additive, personal care products, plastic and rubber products [4]. With the wide variation of industrial and consumer applications there can also be variations of the chemical mixture of glycerin with other supporting chemicals for each specific application. With so many applications for this molecule in both the industrial and consumer markets there is a great demand for this molecule. To account for this there are multiple methods of producing glycerin. There are two main types of production methods which are: natural production and synthetic production. For natural production, glycerine can be collected from plant and animal sources as well as coming from another process as a by-product [5]. One plant source of glycerine can be extracted from soybeans. An example of obtaining glycerine as a by-product is during the soap making process when fatty acid esters are combined with lye and a by-product of this is the chemical glycerine [5]. The natural production of glycerine is limited in its' speed as well as being an expensive. Due to the high demand of glycerine an alternative method was needed to manufacture glycerine. This production method was to synthetically produce glycerine. The synthetic production of glycerine can be made from propene or propylene which is a three carbon petrochemical compound with double bonds [5]. For this method three hydroxy groups are added to the three carbon chain to produce glycerine [5]. Another method of synthetically producing glycerine is to refine a chemically similar molecule. The use of synthetically produced glycerine has increased due to the lower cost of production as well as the increased speed at which the glycerine can be produced.

**Mixture of Water and Glycerine**

For this picture a mixture of water and glycerine was used as the viscous fluid. For the effect that was desired for this piece a fairly viscous fluid was needed to create the envisioned waves and patterns. A 50-50 ratio of glycerine to water was used. This was achieved by mixing 1 cup of glycerine with 1 cup of tap water in the pressure vessel that was used, which was a highly modified tupperware container. The water-glycerine combination was consistently mixed with a stirring device until uniform transparence and thickness was achieved.

$$\nu^{1/3} = x_a * \nu_a{}^{1/3} + x_b * \nu_b{}^{1/3} \quad (1)$$

To estimate the working viscosity of the mixture we can use Gambill's method as described in Equation 1. For Equation 1 x is the percent mixture of both the water and the glycerine being mixed and ν is the kinematic viscosity of each fluid. The percent mixture for both water and glycerine is 0.5 because there is a 50-50 mixture ratio of glycerine to water that was used. The kinematic viscosity of water at room temperature (20 C) is 1.004 $*10^{-6}\ m^2/s$, and the kinematic viscosity for glycerine at room temperature is 6.48 $*10^{-4}\ m^2/s$. Using Equation 1 and the values listed the kinematic viscosity of the 50% mixture of glycerine is now 1.12498$*10^{-4}\ m^2/s$, which is much closer to the kinematic viscosity of the glycerine.

**Fluid Collision and Plateau-Rayleigh**

For this picture the velocity, viscosity, and angle of collision are the most important variables in determines the variations and fluid thread breakup properties. The increase in viscosity was discussed earlier with the fact that the combined mixture of 50% glycerine and 50% water has an increased overall kinematic viscosity over just water.

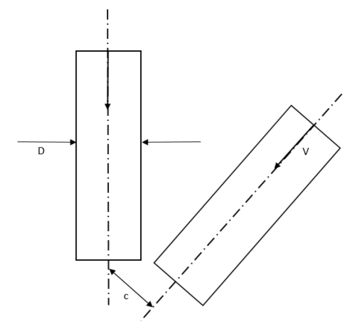


Figure 2: Fluid Collision Schematic

$$\varepsilon = \frac{c}{D} \quad (2)$$

Equation 2 is the dimensionless eccentricity of the collision with c being the distance between the two streams and D being the diameter of the nozzles. This equation gives us information on the angle of incidence between the two streams as well as the diameter of the two flows that are included in the interaction. For the fluid flow that was captured in this piece the eccentricity worked out to equal 0.75.

$$We = \frac{\rho * V^2 * D}{\sigma} \quad (3)$$

Equation 3 is the dimensionless Weber number which is useful when analyzing flows between two fluids especially when curved surfaces are involved. For Equation 3 ρ is the density of the fluid, v is the fluid velocity, D is the diameter of the nozzles, and σ is the surface tension. This equation gives us information on the interaction between the two fluid flows and how the droplets form. For the fluid flow involved in this picture the Weber number turned out to be equal to 50.

$$Oh = \frac{\eta}{\sqrt{\rho\sigma D}} \quad (4)$$

Equation 4 is the dimensionless Ohnesorge number which is useful when analyzing the relation of viscosity and inertia and surface tension forces. When this number is really high it indicates that there is a large influence on the collision interaction is dependent on the viscosity of the fluid. Due to this it can tell us what types of droplets are formed and how the fluid thread breakup should look like. For Equation 4 η is the dynamic viscosity of the fluid, ρ is the density of the fluid, D is the diameter of the nozzles, and σ is the surface tension. For the fluid flow involved in this picture the Ohnesorge number turned out to be equal to 0.5.

The interaction of all of the dimensionless numbers that describe the interaction between the two viscous fluids colliding and describe the Plateau-Rayleigh instability. The Plateau-Rayleigh instability describes the type of fluid breakdown that occurs. The dimensionless numbers described tell us information about the Rayleigh fluid break up, sinusoidal wave break up, wave like break up with air friction and atomization [8]. When we look at the interaction of these numbers we can describe what we can expect from the collision of the two streams.

**Set Up**

To capture the picture a system was set up to establish a set of stable conditions as to which a quality picture could be captured.

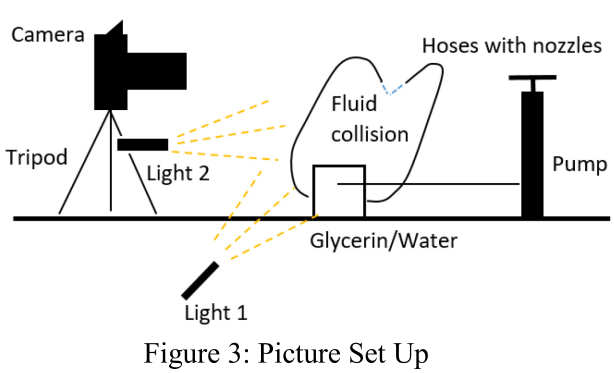


Figure 3: Picture Set Up

The camera was connected to a tripod which is placed upon the table directly in front of the fluid collision. The external light that was used was two bike lights that were placed both directly in front of the collision site and one that was at an angle off towards perpendicular to the camera as well as a fluorescent source which was sufficient for this piece. The use of multiple sources of light was necessary in order to allow enough light into the camera to properly capture a high amount of detail. The water-glycerine mixture was placed into a modified Tupperware container that was pressurized using a bike pump. The pressurization is needed in order to get the mixture to flow at the correct speed to achieve the desired effect. From the pressurized tank there was two hoses that came off of the bottom of the container that were directed at one another and the resulting fluid collision was captured. Behind the fluid collision a black poster board was set up so as to minimize any possible distractions from the background.

**Camera Set Up**

The camera was also set up in a specific way to capture as much of the contrasting color and brightness as possible. The camera that was used in this piece was a Nikon D3200 DSLR with an attached 18-55 mm lens with an additional micro lens attachment. The lens attachment that was used was adequate due to the fact that the jet collisions used were so close in proximity and the detail desired was so micro in scale. There were 4 main manual features on the camera that were used to maximize the quality of this picture. These features were the aperture (f stop or f/number), exposure time or shutter speed, ISO, and the exposure bias.

The aperture on a camera refers to the size of the opening in the optics which light passes through to capture an image. The size of the aperture is one of the major factors that affects the depth of field for any given image. With a small f stop the subject stands out and the background is blurred. The aperture stop is typically referred to as the f stop, which is a ratio of the attached lens's focal length to the diameter of the aperture opening. The range of f stops for the camera used ranged from f/3.5 to f/36. For this picture an f/stop of f/6.3 was used which is not particularly small but did allow an adequate amount of light into the camera to capture the desired details.

The shutter speed, also referred to as the exposure time, is the amount of time that the shutter is open when taking a given picture. This is important when considering whether the desired target is moving at a fast or slow pace. For a relatively fast moving object like the collision of two streams with subsequent droplets a relatively fast shutter speed is necessary to capture as much detail as possible while limiting the motion blur of the droplets. The range of shutter speeds on the camera used went from 1/4000 to 30 seconds. However, one drawback of utilizing a faster shutter speed is that it lets less amount of light into the camera. For this piece, a shutter speed of 1/4000 of a second was used to capture as much detail of the collision and resulting fluid thread breakups.

The ISO sensitivity refers to how sensitive the camera film or in the case of a DSLR how sensitive the sensor is to the incoming light. ISO stands for International Standards Organization and this value just refers to how sensitive the sensor is to a given value of incoming light. For the camera that was used the range of the ISO sensitivity went from 100 to 6400. This value is extremely important when taking pictures at relatively low level light conditions that the source light is not direct but being reflected off of surrounding background. To balance the amount of light that was coming in with the details in the stream collision instability an ISO of 6400 was used. One drawback of using such a high ISO is that it can sometimes be too grainy and doesn't capture so much detail in the picture. But for this piece the ISO level that was needed to counteract the shutter speed that was used in order to allow enough light to come in to be able to capture as much detail as possible.

The final manual feature that was used was the exposure bias, which refers to the feature that allows the user to manually adjust the exposure that is measured by the camera's light meter. On the camera that was used to take the picture this ranged from -3 to 3, and for this piece a -.3 was used. This is because on an artistic approach I as the artist liked what this particular exposure yielded.

After the desired picture was taken a post processing software named Photoshop was used to enhance the picture. For this piece the brightness of the overall picture was increased to 100% of what the original picture was at. In addition, the color of the background was replaced with a pure black color which reduced any and all distraction coming from the background. The contrast was also adjusted to accent the white lines of the droplets which helped to bring more focus onto the phenomena. One important alteration from the original image that should be noted is that the image was cropped and rotated in order to have the stream running perfectly down the center of the image and a clone stamp was used to blend all cropping inconsistencies that were present.

## DISCUSSION & CONCLUSION

The desired result of capturing a full array of detail of two viscous flows colliding. While the sharpness of the droplets coming out of the stream breakup is what I as the artist would have desired, the motion blur that is present around the droplets could be avoided in future iterations with further exploration of camera features as well as lighting conditions. The lighting conditions could be improved upon with utilizing higher quality lighting over the camera light, bike lights, and fluorescent light which could reduce the motion blur that is present in this picture. The dark background made for an interesting contrast with the droplets, but further experiments could be made to adding color or another accenting mixture with the stream interaction so as to highlight the focus even more. Additionally, in future iterations the major factors driving this phenomenon can be altered to create different effects. As mentioned earlier these include the following: the velocity of the viscous fluids as well as the angle of incidence and fluid viscosity.

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