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MCEN 4151: Flow Visualization
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September 30, 2019

Transitional Smoke

I captured this image for the “Get Wet” assignments for the course Flow Visualization. The main purpose of this task was to get familiar with a DSRL camera by capturing an intriguing fluid flow phenomenon and playing with the camera settings and how each affect the image. In this image I was able to capture the transition of laminar to turbulent flow of smoke. I thought this was a very interesting event to capture because of the different states at which the smoke is at.

In order to create this environment, I used a incent stick pointing upwards, so the smoke always rose linearly. This occurs because when the incent burns, the smoke that is released is hotter than the air of the environment. This essentially make the density of the fluid lighter than air’s density making it rise. I places the stick on a table, and I set the camera below the surface of the table. The camera was pointing in a forward-up direction, and had a light shining from the side of both the smoke and camera. The reason why I created this set up was because it allowed me to capture more smoke since the smoke at the top of the image is farther from the camera. I found that you must have a very calm (airflow-wise) environment in order to let the smoke develop as a single body.

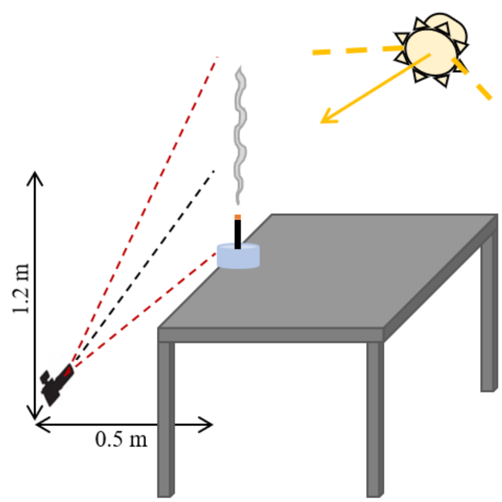

Figure-1: Setup of camera and light

Most of the time, the flow of the smoke was laminar, but whenever an external force was introduced it made it go turbulent. The way I manage to capture the transition was by hitting the desk and waiting for the incest stick to stop vibrating. Once the incest was stationary again, the flow because laminar, however, the top part of the smoke was still at a turbulent state. The reason why an external force can change the flow type of a fluid can be analyzed using Reynolds Number:

$$Re = \frac{\rho v L}{\mu} \quad \text{(Eq-1)}$$

In this equation, ρ is the density ($\frac{kg}{m^3}$), v is the velocity ($\frac{m}{s}$), L is a linear dimension (m), and μ is the dynamic viscosity (Pa*s). We can see that ρ, L, and μ are constant since they are properties of the fluid, this leaves us with velocity being the only factor that can affect Reynolds Number. From Newton's 2^{nd} Law (F=ma), we can see that when we introduce a force on a constant mass, we make it accelerate. Whenever I applied a force to the table, the incent would start to vibrate casing the smoke to have a higher release velocity (v). From Eq-1 we can see how a higher velocity will lead to a higher Re number. A fluid flow is laminar if the Re is less than 2,100 and turbulent if its more than 4,000. So, we know the top smoke (created by vibration) is experiencing turbulent flow since it had a larger velocity. In the other hand, the smoke created by the stationary incent is laminar because of its small Re.

The source of smoke for this image is an amber-sandal smell incent stick manufactured by HEM Corporation. In order to recreate, the environment most be indoors where the environment airflow is calm and does not disturb the flow of the smoke. The room must have all light off except for one, which should be pointing the smoke sideways at about 90°. This is very important because it allows the camera to capture the fluid without causing any reflections or diffractions of lights. I would also recommend using a gray background because black background will make the smoke stand out more but will not let you see the incent stick.

I used a Nikon 3200 DSLR camera with an AF-S 35mm lens to capture this image. The maximum aperture of this lens is 1.6 with a focal length of 35mm. I set my exposure time to 1/1600 sec and my ISO at 6400 because I wanted to capture every detail of the smoke that would make it look stationary. Also, since the room was kind of dark, I set my f-stop to f/2. The image has a dimension of 6016x4000 pixels. For this shot, I specifically focused on the smoke cluster since that's the densest area of the image. After I took the shot, I edited my photo on gimp. Using the curve color, I was able to set a darker background which allowed me to make the smoke stand out more.

Figure-2: Raw picture before editing

References

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Abramovici, Alex, and Zeev Vager. “Test of Newton’s Second Law at Small Accelerations.” *Physical Review D*, vol. 34, no. 10, 1986, pp. 3240–3241., doi:10.1103/physrevd.34.3240.