

Smoke Wisps

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Flow Visualization, MCEN 5051

Image / Video Assignment #4

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Introduction

For the final project I wanted to try something challenging and interesting that would expand my skill set. I decided to use lasers to visualize the flow of smoke. Photography is literally art made with lighting, and I have never tried to use lasers to light an image before. Overall this project was fun, insightful, and a strong success.

Fluid Dynamics Used

Convection Currents:

Hot air tends to flow upward due to what we call convection currents. This effect is mainly due to density differences between the cold and hot air. The hot air is less dense than the cool air and thus has less mass per unit of volume, which makes the hot air more buoyant than the cold air. The buoyant forces made by gravity and pressure from the cold air, cause the hot air to rise. This effect creates convective mixing, which stems from adding circulation into the flow and promotes turbulent instabilities.

$$\rho_{air,cold} > \rho_{air,hot}$$

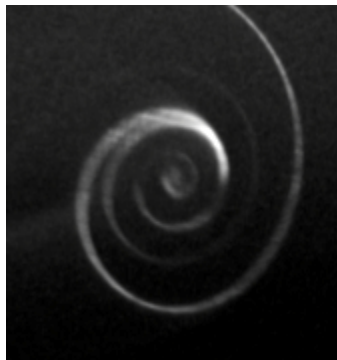
Convective Diffusion:

Diffusion describes how the smoke in the air is dispersed. It explains how good at mixing a flow is. For example laminar flow has bad diffusion properties while turbulent flow is the opposite. Here is the general Convective-Diffusion Equation:

$$\frac{\partial c}{\partial t} = \nabla \cdot (D\nabla c) - \nabla \cdot (\mathbf{v}c) + R$$

Eddy:

An Eddy is the swirling of fluid that is created in turbulent mixing and the reverse current in a turbulent regime. Many of these can be seen in the video but a great example is shown below:



Eddy Diffusion:

Eddy diffusion is a modified form of convective diffusion that adds in the effects of turbulent mixing as a coefficient to the convection-diffusion equation. This type of fluid analysis is mainly used at large scale in atmospheric calculations and studies.

Producing the Flow

This setup was very easy. For this image all that is needed is a source of smoke or vapor. To do this, I simply lit a wax candle (out of frame in the video) and blew out the candle. The smoke that came off the wick was used for the video.

Camera Setup and Image Acquisition

This video was exposed with a laser. To do this I had to turn a simple point laser into a plane laser. This actually proved to be quite simple. A laser pointed at clean brushed metal, will essentially reflect a plane laser. I found brushed stainless steel to be the best at this. Next, I placed my camera on a tripod and focused the lens on where the smoke would be. After a little experimenting, I was able to find the right exposure settings to see the smoke clearly illuminated by the laser. For this video I used a Canon 1dx mark II shooting at 59.97fps in 4k. I am using a shutter speed of 1/500 and an ISO of 1600. I also am using a 50mm f/1.8 lens. The video was edited in adobe premiere and the only changes to the footage was a simple black and white filter. The laser was originally green, and thus so was the smoke. I changed this to black and white to add clarity to the video.

Conclusion

The goal of this video was to use a laser to create a visually interesting and beautiful creative piece. I was less focused on the flow and more focused on the lighting and acquisition and I think it made for a really cool video. I was really pleased with how this one turned out.

References

Music Rights : Adobe Music Library

https://en.wikipedia.org/wiki/Combustion#Liquid_fuels

<https://en.wikipedia.org/wiki/Convection>

https://en.wikipedia.org/wiki/Diffusion_equation

[https://en.wikipedia.org/wiki/Eddy_\(fluid_dynamics\)](https://en.wikipedia.org/wiki/Eddy_(fluid_dynamics))

https://en.wikipedia.org/wiki/Eddy_diffusion