Vortices around a Cylinder

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1 Introduction

This study centers on visualizing Von Kármán vortices, intricate patterns formed in the wake of a moving cylinder in a fluid. Colored dye was introduced to visualize these vortices, adding an artistic element to the scientific study. The Canon Rebel T3i DSLR camera, paired with a zoom lens, was employed to capture this visually rich experiment.

The intentional marriage of scientific rigor and artistic expression aims to highlight the captivating beauty found in the harmonious interplay of colors and patterns within a controlled environment. By exploring the convergence of science and art, this study not only contributes to scientific knowledge but also invites appreciation for the aesthetic allure embedded in the meticulous exploration of Von Kármán vortices.

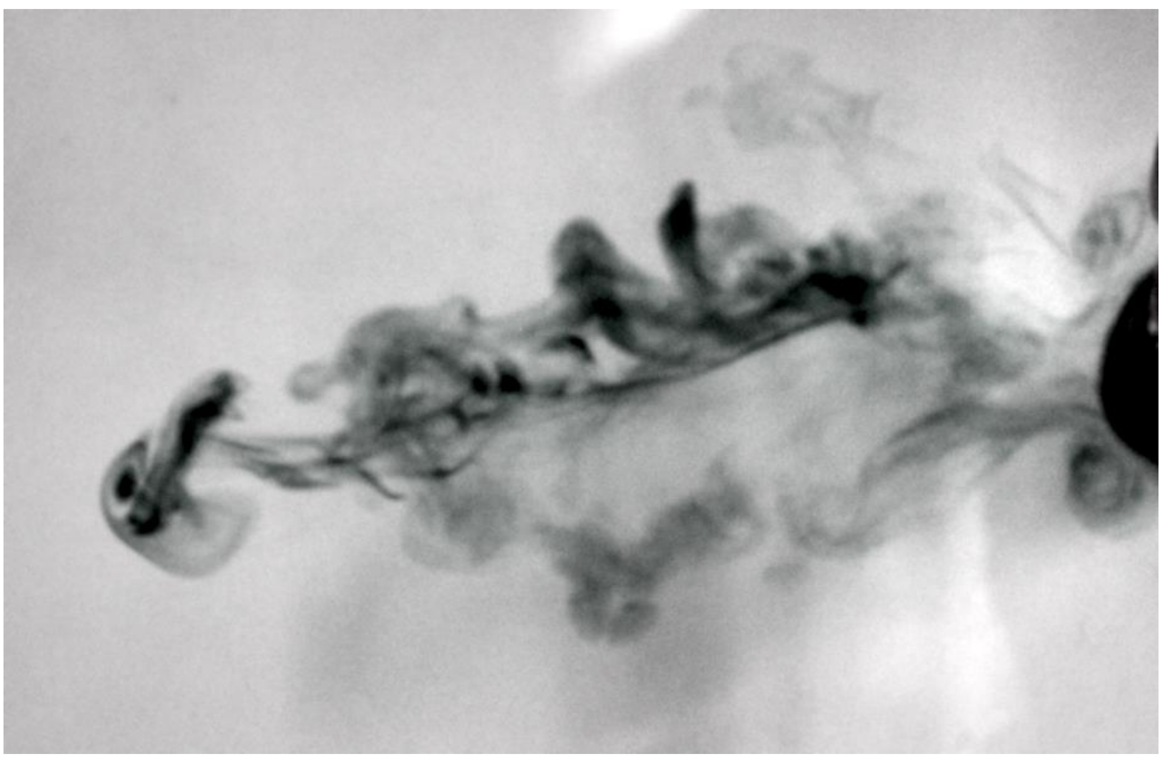

Fig 1: Final image of Von-Karman vortices

2 Flow Phenomenon

Von Kármán vortices, named after physicist Theodore von Kármán, occur when water flows past a solid object, creating swirling patterns in its wake [1]. However, in the case of this image, the body was moved while the water remained stagnant. The theory behind the formation of the vortices is explored in more detail in the following paragraphs.

2.1 Vortex Formation:

Cylinders immersed in moving fluid flows with Reynolds numbers spanning from 100 to 10^5 generate alternating vortices of opposite rotation. These vortices collectively create a pattern known as a "von Kármán vortex street" in the wake of the cylinder. As a result, a force is exerted on the cylinder perpendicular to the flow, with the direction of this force changing each time a vortex is produced. The same vortices can also be observed when moving the cylinder at similar ranges of Reynolds Numbers in a stagnant fluid [2].

Reynolds number for a flow is a measure of the ratio of inertial to viscous forces in the flow of a fluid around a body in a channel, and may be defined as a nondimensional parameter of the global speed of the whole fluid flow:

$$\mathrm{Re}_L = \frac{UL}{\nu_0}$$

Where *U* is the freestream flow speed, *L* is the characteristic length parameter of the body or channel and ν_0 is the free stream kinematic viscosity of the fluid.

2.2 Vortex Shedding Frequency:

The frequency at which vortex shedding takes place for an infinite cylinder is related to the Strouhal number St by the following equation:

$$\mathrm{St} = \frac{fD}{V}$$

Where f is the vortex shedding frequency, D is the cylinder diameter, and V is the flow velocity. The Strouhal number varies between 0.18 and 0.22 [3].

3 Methods

The materials used in the experiment are as follows:

- A 3 cm diameter cylinder of height 10 cm.
- DSLR Camera
- 3 ft water tank
- Food coloring dyes: green
- 1 ml syringe with an 18-gauge needle

3.1 Procedure

The tank was filled with water up to 15 percent of its height. The syringe with an 18-gauge needle was filled with colored dye. Next, the cylinder was placed into the water while the camera was adjusted for focus. The dye was then injected behind the cylinder, after which the cylinder was slowly moved through the fluid. The dye ended up forming the wake of vortices behind the cylinder, which was captured by the camera.

3.2 Camera

The camera used was a Canon Rebel T3i 600D 18 MP Digital SLR Camera with an 18-55 mm zoom lens. The camera settings for the final image are as follows:

Table 1: Camera Settings

Lens	Canon EF-S 18-55mm f/3.5-5.6 IS II
Focal Length	55 mm
Aperture	f/5.6
Exposure	1/80
Focus Distance	0.31 m
ISO	1000

3.3 Post-Processing

Post-processing was done in Darktable to crop out the image to get the desired frame. Adjustments were made to enhance contrast and brightness by changing the RGB curve. The color contrast was adjusted to give the image a black-and-white filter. The pixels in the original image are 5198 x 3462 (pixels) and those in the final edited image are 931 x 600 (pixels).

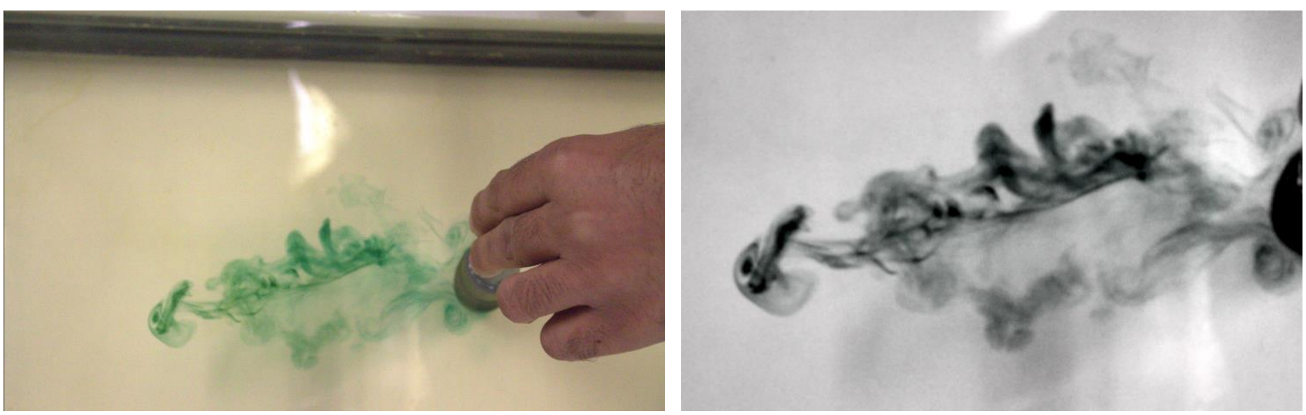

Fig 4: a) Original Image b) Final edited image

4 Observations

The photograph adeptly depicts the von Kármán vortex street formed in the wake of a dynamically moving cylinder. However, achieving a sharp focus posed a significant challenge during this experiment. This difficulty stemmed from both the depth of field and the motion introduced by the flowing dye and the continuous movement of the cylinder.

One potential solution to enhance focus and clarity is to transition to a 2-dimensional flow by implementing a laser sheet. This modification could help mitigate the depth of field issues, providing a more precise and detailed visualization of the von Kármán vortex street. Additionally, considering the use of rheoscopic fluids with characteristics of greater stability and reduced transience may offer improved results. Such fluids have the potential to capture flow details over a more extended period, thus enhancing the overall observational quality.

5 Conclusion

In conclusion, our study on Von Kármán vortices blends scientific inquiry with artistic expression. The Canon Rebel T3i DSLR camera vividly captures the intricate patterns formed in the wake of a moving cylinder in fluid. While shedding light on vortex formation and shedding frequency, the experiment highlights challenges like achieving sharp focus. Proposed solutions include transitioning to a 2-dimensional flow with a laser sheet. Exploring alternative materials like rheoscopic fluids holds promise for improved observations. In essence, this study not only deepens our understanding of fluid dynamics but also emphasizes the aesthetic allure inherent in Von Kármán vortices.

Acknowledgments

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References

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[2] Duranay, A., Demirhan, A. E., Dobrucalı, E., & Kınacı, Ö. K. (2023). A review on vortex-induced vibrations in confined flows. *Ocean Engineering*, 285, 115309. https://doi.org/10.1016/j.oceaneng.2023.115309

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