University of Colorado - Boulder
MCEN 4151
Flow Visualization
Team Second Report
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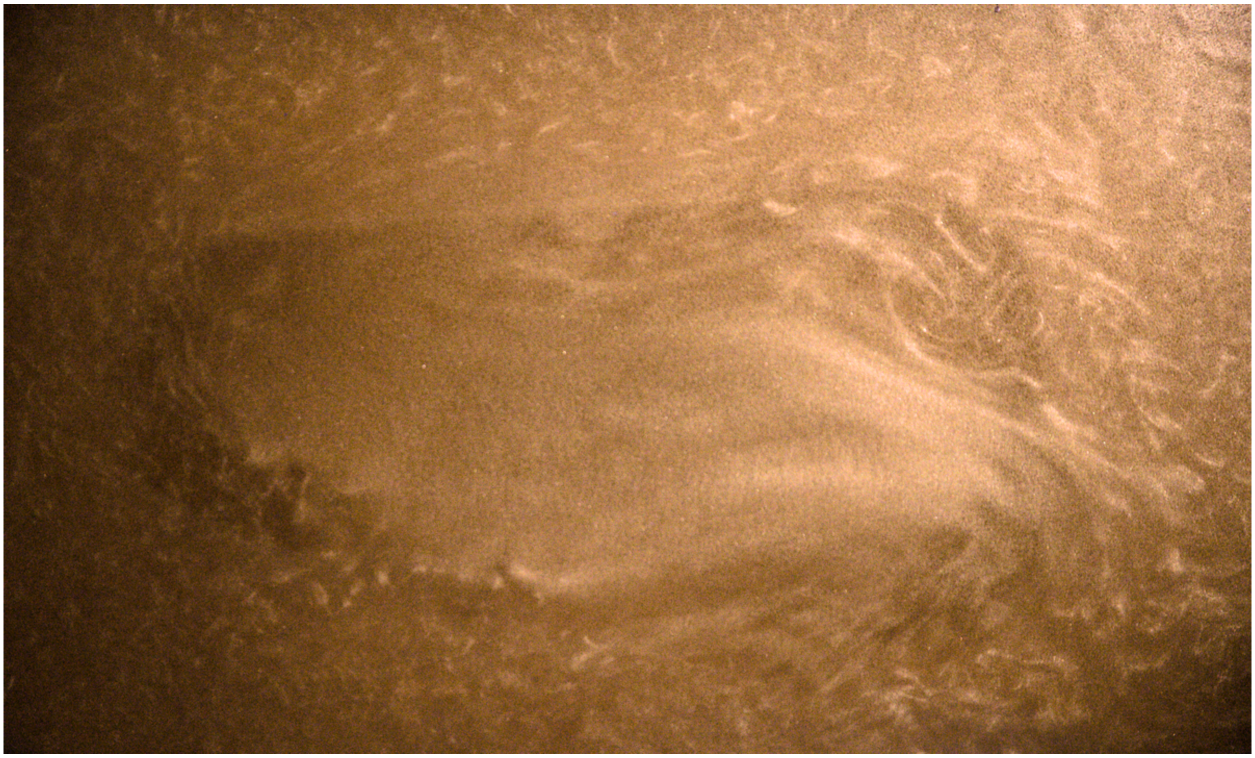

1. Introduction

1.1 Image Summary

The presented image captures continuous, circular flow in an open-top tank filled with a water and mica flake mixture, observed from above. This circular flow pattern was achieved by allowing a water pump to circulate the fluid, emphasizing rotational and shearing interactions in the liquid. The choice of mica as a tracer adds a shimmering quality to the flow, enhancing the visibility of surface motion and flow patterns.

1.2 Motivation

This flow visualization highlighted shearing and rotational interactions within a fluid, focusing on capturing surface textures created by circulating flows. The artistic objective was to produce a visually engaging image that captures fluid movement with high contrast, frozen motion, and aesthetic appeal. By modifying color tones in post-processing, the image reveals unexpected flow dynamics and amplifies the visual impact of the swirling mica patterns.

2. Methodology

2.1 Test Setup

The experiment was conducted in an open-top acrylic tank, measuring 11” × 22” × 1”, with a capacity of approximately 3.96×10^{-3} m^3. The tank was filled to about half of its volume with water, into which approximately 6 grams of mica powder were added. A water pump was positioned to create a circular motion by recirculating water from one side of the tank to the other, maintaining a flow rate of approximately 4 liters per minute. This setup generated high and low-pressure zones in the tank, enhancing visible flow characteristics. Unlike the original setup, this configuration allowed for a circular flow path, contributing to the unique swirling patterns seen in the image.

2.2 Visualization Technique

The visualization relied on mica flakes suspended in water, which act as tracers by aligning themselves along the flow. The anisotropic properties of mica result in a visually distinct appearance depending on particle orientation, creating contrasting flow regions based on fluid movement and lighting conditions. This setup allowed for intricate patterns to form, showcasing fluid vorticity, mixing effects, and surface wave interactions within the tank.

2.3 Photographic Technique

The photograph was taken with a Canon EOS 6D Mark II, using an EF 28-135mm f/3.5-5.6 IS lens, with a shutter speed of 1/500 seconds, an ISO of 800, and an f-stop of 5.6. The setup involved lighting from multiple LED lamps placed around the tank, with additional focus lighting from above. This lighting strategy highlighted surface reflections and enhanced the texture of the flow, giving the image depth and detail. The image was edited in Adobe Lightroom Classic to emphasize contrast, adjusting color channels to produce a warm hue, which gives a distinctive visual effect to the otherwise colorless flow patterns.

3. Flow Analysis

3.1 Estimation of Flow Speed

Based on the pump’s flow rate of approximately 4 liters per minute (or 0.067 liters per second), we can estimate an average flow speed within the tank. Assuming a circular path with a radius of approximately 5.5 inches (0.14 meters, half the width of the tank), we can use the following relationship to estimate flow speed:

$$Q = A \bullet v$$

where:

- Q is the flow rate (0.067 L/s),
- A is the cross-sectional area of flow,
- v is the average flow velocity.

Assuming an effective depth of 0.1 meters (approximate half-tank fill level),

we get:

$$A = 2\pi r \bullet depth \approx 2\pi(0.14m)(0.1m) = 0.088m^2$$

Solving for v:

$$v = \frac{Q}{A} = \frac{0.000067m^3/s}{0{,}088m^2} \approx 0.76m/s$$

This flow speed is a rough estimate, providing a general idea of the average velocity in the tank.

3.2 Shear Rate Estimation

The shearing observed in the fluid can be attributed to the velocity gradient created by the water pump. Shear rate (γ) in a circular flow can be estimated as:

$$\gamma = \frac{\Delta v}{\Delta r}$$

where:

- Δv is the difference in velocity across a radial distance,
- Δr is the radial distance over which the velocity changes.

Assuming a difference in velocity of approximately $0.5m/s$ over a radial distance of $0.1m$ (inner to outer flow regions near the pump):

$$\gamma = \frac{0.5m/s}{0.1m} = 5s^{-1}$$

This shear rate reflects the relative intensity of flow deformation within the tank, influencing the swirling patterns visible in the mica distribution.

3.3 Reynolds Number Calculation

To characterize the flow regime, we calculate the Reynolds number (ReReRe), given by:

$$Re = \frac{pvd}{\mu}$$

where:

- p is the density of water (approximately $1000\ kg/m^3$),
- v is the estimated average velocity (0.76 m/s),
- d is the diameter of the circular flow path (approx. 0.28 m),
- μ is the dynamic viscosity of water ($\approx\ 0.001\ Pa \bullet s$).

$$Re\ = \frac{1000\times0.76\times0.28}{0.001} \approx\ 212800$$

A Reynolds number in this range (on the order of 10^5) indicates turbulent flow, which aligns with the visual complexity of swirling and mixing seen in the image.

4. Conclusion

This project emphasized the importance of lighting, camera settings, and flow manipulation in capturing specific flow patterns. The analysis provided a better understanding of flow speed, shear rates, and the turbulent regime, shedding light on fluid behavior in a controlled setting. The use of mica as a tracer particle effectively visualized flow structures, revealing areas of shear and rotation while adding aesthetic depth to the image. Future work could involve more precise measurement techniques to capture the velocity profile and shear stress distribution across different flow regions.

5. References

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