CU Boulder

Team First Report

MCEN 5151-002

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Introduction

This image was produced for a flow visualization project with the objective of capturing the interaction between a free-falling water jet and a stationary reservoir. The purpose was to investigate how turbulence develops as momentum from the incoming stream is transferred into the quiescent fluid. The original goal of the team photo was to create a thermal convection cell, but due to issues with set-up, this report focuses on a different experiment that was successful. Glitter particles were introduced into the flow to serve as passive tracers, enhancing visibility of entrainment and small-scale vortical structures generated during the mixing process. Several preliminary configurations were attempted, but the arrangement of a water jet entering a transparent vase of still water provided the most effective combination of clarity and visual contrast. The final setup successfully highlighted both the penetration of the jet and the subsequent dispersion of particles.

Context and Purpose

The flow apparatus consisted of a clear glass vase, approximately 12 inches in height and 4 inches in diameter, filled with still tap water at room temperature. A stream of water was poured vertically from a height of about 5 inches above the free surface using a handheld container. A schematic of this set-up is shown in Figure 1.

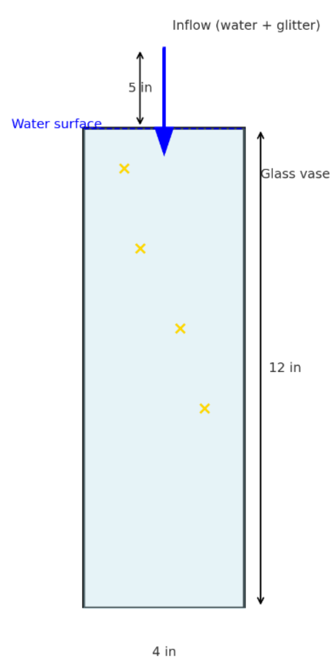

Figure 1. Flow Visualization Set-Up

To visualize the motion, metallic glitter particles with a characteristic size of roughly 0.005–0.01 inches were mixed into the inflowing water, allowing the jet penetration, entrainment, and dispersion within the reservoir to be observed. The flow configuration can be described as a free liquid jet entering a quiescent reservoir, producing a submerged turbulent jet that entrains ambient fluid and forms vortical structures during the mixing process. The inflow velocity was estimated based on free-fall from a height of 5 inches (0.417 ft). Using the kinematic relation $V = \sqrt{2gh}$, with $g = 32.2\ \text{ft}/s^2$ and $h = 0.417\ \text{ft}$, the jet velocity is approximately $V \approx 5.2\ \text{ft}/s$. Taking a characteristic jet diameter of 0.4 inches (0.033 ft) and water's kinematic viscosity of $1.08 \times 10^{-5}\ \text{ft}^2/s$, the Reynolds number is calculated as

$$Re = \frac{VD}{\nu} = \frac{(5.2\ \text{ft}/s)(0.033\ \text{ft})}{1.08 \times 10^{-5}\ \text{ft}^2/s} \approx 1.6 \times 10^4.$$

This value confirms that the incoming jet is fully turbulent. The high Reynolds number explains the rapid breakup of coherent structures into smaller-scale turbulence inside the vase. The glitter tracers highlighted entrainment at the jet boundary, where velocity gradients between the jet and the quiescent water generated shear-layer instabilities. These instabilities rolled up into vortices and promoted mixing, behavior consistent with established descriptions of turbulent jet development (Hussein, Capp, & George, 1994; Pope, 2000). The flow was unsteady, with glitter dispersing further into the reservoir as the jet's momentum dissipated.

Visualization Technique

The visualization was achieved by adding metallic glitter, sourced from standard craft materials, into the inflowing water stream. Particle sizes ranged from approximately 0.005 to 0.01 inches, and a small quantity was sufficient to trace the jet path without obscuring the flow. The reflective surfaces of the glitter enhanced visibility and contrast against the clear water, making entrainment and mixing readily observable. The experiment was conducted indoors under ambient room lighting with a phone camera flashlight off to the side to add an extra element of glitter reflection.

Photographic Technique

The image was captured using a Canon EOS Rebel T3i digital camera equipped with an EF-S 18–55 mm f/3.5–5.6 lens. The field of view encompassed the full height of the vase, with the camera positioned approximately 18 inches from the subject to minimize distortion while still framing the entire setup. The vase was set in front of black fabric to obtain the dark background. The focal length was set near 35 mm to balance magnification with depth of field, ensuring that both the inflowing jet and suspended glitter remained in focus. The digital image resolution was 1920 × 1280 pixels in its original form, later cropped slightly with a subsequent resolution of 887 x 1280. Exposure settings were based on the indoor lighting and fast-moving process of water pouring with an aperture of f/4.5, shutter speed of 1/1060 s, and ISO 6400 to accommodate indoor lighting. Post-processing was limited to minor adjustments of brightness and contrast to improve distinction between the glitter tracers and the background, without altering any flow features.

The original photo is shown in Figure 2 below.

Figure 2. Original Image

Conclusion

The final image captures the development of a turbulent jet as it enters a still reservoir, with glitter tracers revealing entrainment and mixing at the jet boundary. The reflective particles provided strong visual contrast, though clustering in some regions reduced clarity. Overall, the image effectively demonstrates turbulent jet behavior at high Reynolds number, meeting the intent of visualizing complex mixing in a simple tabletop setup. Future improvements could involve more controlled lighting or refined tracer selection to better resolve smaller-scale features.

References

1) Hussein, H. J., Capp, S. P., & George, W. K. (1994). Velocity measurements in a high-Reynolds-number, momentum-conserving, axisymmetric, turbulent jet. *Journal of Fluid Mechanics, 258*, 31–75. https://doi.org/10.1017/S002211209400323X

2) Pope, S. B. (2000). *Turbulent Flows*. Cambridge University Press. https://doi.org/10.1017/CBO9780511840531