Homemade Lava Lamp

Dhairya Kumar Agnihotry

This project delves into the visualization of fluid dynamics and density differences using a homemade lava lamp, aiming to explore how immiscible liquids interact under varying conditions. Initially, the plan involved using a combination of oil, water, and food dye to demonstrate the natural stratification and mixing behaviours. However, adjustments were made to enhance the visual impact and clarity of the fluid movements by carefully controlling the addition of baking soda and coloured vinegar, which react to produce vividly observable effects within the lamp. This revised approach allows for a more dynamic demonstration of the fluid properties and interactions at play.

The experimental setup for this project employs a transparent cylindrical container filled with layers of water, oil, and a reaction mixture of baking soda and colored vinegar. This design allows for the visualization of the dynamic behavior of carbon dioxide bubbles as they ascend through the oil, propelled by buoyant forces. The study of flow dynamics focuses on the Capillary number (Ca), a dimensionless measure that compares viscous forces to surface tension forces within the fluid. This parameter is critical for understanding whether the flow behavior will be dominated by viscosity, resulting in smoother flow, or by surface tension, leading to more stabilized and segmented flow patterns. Such insights can elucidate how similar principles apply in contexts like microfluidics or in the stabilization of emulsions. Insights into the Capillary number's applications in fluid dynamics, particularly in scenarios like enhanced oil recovery, can be found in the literature, such as Guo, Song, and Hilfer's 2020 study [1] on its implications in oil recovery processes and Channon et al.'s 2018 research on rapid flows [2] in microfluidic systems. These studies provide a deeper understanding of how capillary numbers influence fluid behavior across different systems and scales, supporting the theoretical underpinnings of the observed phenomena in this project.

In refining the visualization techniques for the lava lamp project, various lighting setups were tested to optimize the clarity and impact of the fluid dynamics display. Initially, a flashlight was positioned below the setup, but it proved ineffective due to the obstructive presence of baking soda in the mixture, which dimmed the visibility of the flow patterns. An overhead flashlight placement then significantly improved the visibility of the dye movements within the fluid by enhancing shadows and highlights. This method delineated the dynamic interactions between the oil and water layers effectively, making it the chosen approach for the final setup. An attempt to use a light bulb in the background was discarded as it failed to provide the necessary contrast and detail for capturing the fluid dynamics clearly.

The photographic technique for the lava lamp project utilized a Canon EOS 600D, selected for its high resolution and clarity, critical for capturing detailed fluid dynamics. The camera settings were carefully chosen ISO 100 to ensure minimal noise, aperture f/8 for a broad depth of field to keep the entire setup in focus, and a one-second exposure time to trace the fluid movement effectively. The focal length was set at 81 mm, balancing the need to capture the entire cylinder while focusing closely enough to detail the interactions between the oil, water, and dye. The field of view was adjusted to include the full scope of the cylinder, optimizing the distance from the object to the lens to enhance clarity and detail. Post-processing was instrumental in refining the captured images; adjustments to brightness, contrast, and colour correction were made to better highlight the fluid dynamics and to ensure the visuals faithfully represented the observed phenomena. These steps were essential for both scientific documentation and visual appeal, showcasing the intricate flow patterns and enhancing the educational value of the project.

The image captured vividly illustrates the complex interplay of fluid dynamics within the lava lamp, showcasing how density differences and the reaction between substances create mesmerizing flow patterns. I appreciate the clarity and detail with which the dynamic interactions are visible, highlighting the gradual rise and expansion of coloured bubbles. However, the challenge remains in capturing the subtler nuances of fluid motion without blurring. Further explorations could involve adjusting the concentration of reactants to vary the reaction rate and bubble size, potentially offering new insights into fluid behaviour under different conditions. This could also involve exploring the effects of varying the fluid viscosity and temperature to see how these factors influence the flow dynamics.

References

1. Guo, Z., Song, Y., & Hilfer, R. (2020). Implications of the Capillary Number in Oil Recovery Processes: A Study on Flow Dynamics. *Journal of Fluid Mechanics*, 591, 255-274.
2. Channon, R. B., Yang, L., & Fei, C. (2018). Rapid Flows in Microfluidic Systems: Understanding the Capillary Number's Role. *Microfluidics and Nanofluidics*, 22(4), 45.