Team Third Report

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MCEN 5151-002

12/4/2024

This video represents my third team project for the flow visualization course, where the focus was on capturing the behavior of entrapped air escaping from liquid two-part silicone under vacuum. The intent of this video was to visually explore and document the degassing process, specifically observing how air bubbles expand, rise, and collapse as the pressure decreases in the vacuum chamber. The phenomenon highlights the dynamics of gas trapped in a viscous fluid when subjected to external pressure changes, a critical process for producing defect-free silicone in industrial and laboratory applications. Initially, achieving a clear and visually compelling image required several trials. Early attempts suffered from poor lighting, inconsistent silicone preparation, and suboptimal camera angles, which obscured key details of the phenomenon. Through collaboration and iteration, these issues were resolved. I worked independently on this project, setting up the equipment, preparing the silicone, and filming the process. This video serves as a visual and educational tool to understand degassing mechanics, and it bridges concepts from physics, fluid dynamics, and materials science.

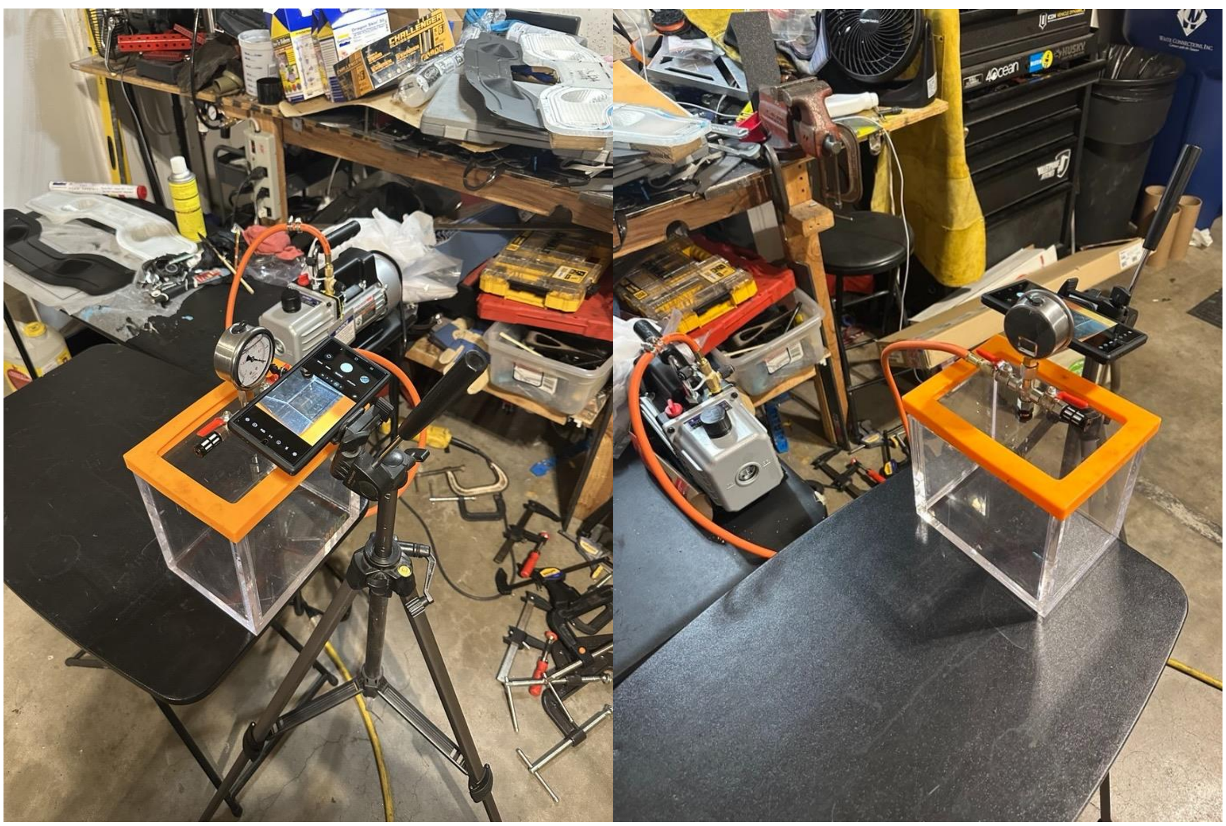

Image 1 & 2: Different angles of the same set up for filming silicone in vacuum chamber

The flow apparatus used for this project consisted of a small vacuum chamber designed for degassing, paired with a standard tripod-mounted smartphone to record the process. The vacuum chamber measures approximately 8-inch length, 6-inch width, and 8 inches in height, and is made of ¾" thick acrylic to aid in visual observation of the silicone or other materials that may be used in the chamber. A silicone sample, prepared in a small mixing container about 3 inches in diameter and 2 inches deep, was placed at the center of the chamber. The chamber was connected to a 3CFM vacuum pump capable of reducing the internal pressure to a constant 29 inHg. The smartphone camera was positioned approximately 2 inches away from the chamber, aligned with the top of the mixing cup and above the vacuum chamber. A picture of the setup has been included (image 1 & 2 above), detailing the vacuum chamber, the tripod, and the camera position relative to the silicone sample. The observed flow involved the expansion, rise, and collapse of entrapped air bubbles in the silicone under reduced pressure. The process was driven by the pressure differential between the trapped air and the vacuum, causing the air to expand rapidly and form visible bubbles. As these bubbles coalesced and rose to the surface, the silicone's viscosity resisted rapid flow, creating a foam-like texture before the air escaped completely.[1] The flow physics was influenced by the balance of forces acting on the air and the silicone, primarily buoyancy, viscous resistance, and pressure gradients. The Reynolds number for the flow can be estimated as:

$$Re = \frac{\rho U L}{\mu}$$

Where ρ is the density of air (1.225 kg/m3), U is the estimated velocity of the rising bubbles (0.01 m/s), L is the bubble diameter (0.005 m), and μ is the viscosity of silicone (0.5 Pa):

$$Re = \frac{(1.225)(0.01)(0.005)}{0.5} = 0.00125$$

This extremely low Reynolds number indicates that the flow was dominated by viscous forces, consistent with the slow and controlled motion of the bubbles.[2] The observed behavior changed over time as the bubbles grew larger, coalesced, and eventually collapsed under the silicone's weight, a result of decreasing air pressure in the chamber. For further context, research on degassing silicone suggests that the process is crucial for achieving defect-free materials, particularly in applications requiring optical clarity or structural integrity. Additional literature was consulted to validate the physical principles, including studies on viscous flow under low-pressure environments and the dynamics of bubble collapse in non-Newtonian fluids. These insights highlight the significance of degassing as a controlled process influenced by fluid properties and external pressure changes.

[1] Easy Composites, "How and Why to Degas Silicone Rubber and Casting Resins," accessed December 5, 2024, https://www.easycomposites.co.uk/learning/how-and-why-to-degas-silicone-rubber-and-casting-resins.

[2] J. Timmermans, "The removal of dissolved and entrained air from liquids," *Thermochimica Acta* 123, no. 1 (1988): 25-50, https://doi.org/10.1016/0377-0257(88)85025-0.

The visualization technique for this project involved observing the escape of entrapped air from a liquid two-part silicone under vacuum. The silicone used was Dragon Skin 30, a commonly available product with a Shore durometer of 30, which was mixed according to the manufacturer's instructions (1:1 ratio by weight) and poured into a small container for degassing. The shop environment was maintained at a temperature of 68°F, ensuring consistent viscosity and behavior of the silicone during the process. The reduced pressure in the vacuum chamber caused air bubbles to expand, rise, and collapse, visually showcasing the degassing phenomenon without the need for additional dyes or markers. Lighting for the image was provided by standard garage LED lights positioned directly above and around the setup. These lights ensured even and diffuse illumination of the clear acrylic vacuum chamber, reducing reflections and enhancing visibility of the bubbles and their motion. The camera, mounted on a tripod, relied on its built-in exposure settings to capture the process without flash, as the steady LED lighting provided sufficient clarity and contrast for documenting the phenomenon. This setup is simple to replicate in a similar environment with comparable materials and equipment.

The video of the degassing process was captured using a Samsung Galaxy S24 Ultra, a digital smartphone camera with advanced photographic capabilities. The field of view was approximately 8 inches wide, encompassing the entire vacuum chamber and its contents. The camera was positioned 8 inches away from the silicone sample, allowing for a clear view while minimizing distortion. The lens used was the smartphone's primary wide-angle lens, with a focal length of 23mm (35mm equivalent). The original video resolution was 3840 x 2160 pixels (4K UHD), ensuring high detail and clarity. The video was shot at 30 frames per second (fps) for smooth motion capture. Exposure settings included an aperture of f/1.7, a shutter speed of 1/60s, and an ISO of 200, chosen to balance brightness and reduce noise in the well-lit environment. Standard LED garage lighting provided consistent illumination, making additional light sources unnecessary. Post-processing of the video was minimal, performed using MiniTool MovieMaker. Adjustments included slight cropping to center the subject, brightness and contrast tweaks to enhance bubble visibility, and stabilization to ensure a steady view. No additional filters or special effects were applied other than slowing down the video. A comparison between the raw footage and the processed video shows improved clarity and focus on the degassing phenomenon, emphasizing the air bubbles' behavior while maintaining the original video's scientific accuracy. This straightforward setup and processing approach makes it easily replicable.

The video reveals the dynamic process of air escaping from liquid two-part silicone during degassing. As the vacuum is applied, bubbles expand rapidly, rise to the surface, and coalesce before collapsing. This visually highlights the relationship between pressure changes and gas behavior in a viscous medium. What I particularly like about the video is the clear depiction of the bubbles' formation and motion, effectively demonstrating the principles of fluid physics, including buoyancy, viscous resistance, and the pressure gradient driving the process. The LED lighting and high-resolution camera allowed for crisp details, making the phenomenon easy to observe and analyze. However, I found some limitations. The uniform lighting occasionally caused reflections on the vacuum chamber's acrylic surface, slightly obscuring certain details. Additionally, the background could have been darker to improve contrast and focus on the silicone's behavior. The fluid physics is well-represented, but questions remain regarding the precise relationship between bubble size, rise velocity, and viscosity over time. Further analysis with quantitative measurements, such as tracking bubble dimensions and speeds, could enhance understanding. My intent to capture and illustrate the degassing process was largely fulfilled, though I would like to improve the visual clarity by experimenting with better lighting and camera positioning. To develop this idea further, I could incorporate additional visualization techniques, such as using a high-speed camera to capture more detailed dynamics or introducing dyes to highlight flow patterns in the silicone. Future iterations could also explore different silicone viscosities or environmental conditions, providing a broader perspective on the degassing phenomenon.