Investigating Parameter Effects on Bubble Formation of the *Alpheus heterochaelis* (Snapping Shrimp) Claw

Neta Glaser, Alexander Ramirez, Austin Simons, Dr. Veronica Eliasson
Department of Aerospace and Mechanical Engineering, University of Southern California, Los Angeles, CA 90007 USA

Introduction

Alpheus paracrinitus snapping shrimp[1]

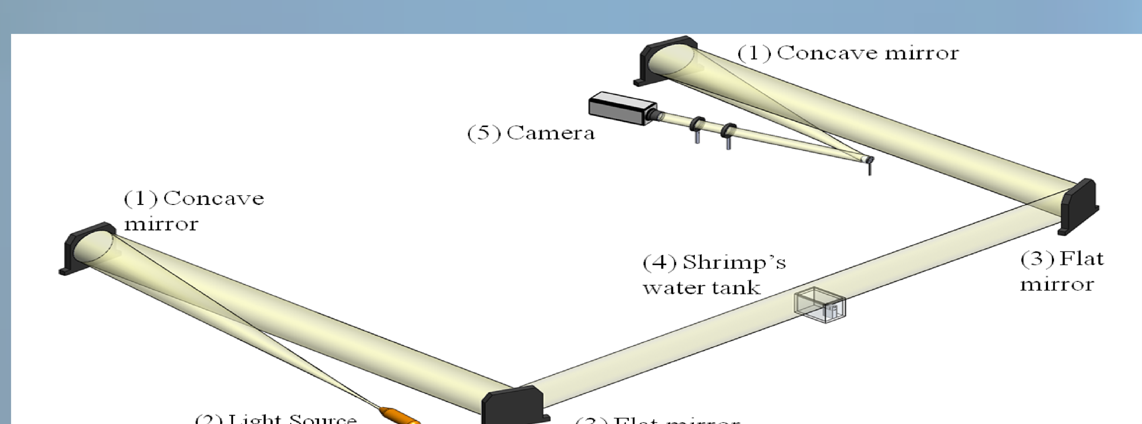
The *Alpheus heterochaelis*, better known as the Pistol Shrimp or Snapping Shrimp, possesses an oversized claw that creates a cavitation bubble upon rapid closure underwater. The implosion of this bubble results in a shockwave which the shrimp uses to stun or even kill its prey[2]. In this research, a mechanical claw has been developed to match the shrimp's geometry on a 14:1 scale. The claw is contained in an aluminum tank with acrylic windows for high-speed Schlieren imaging of shock dynamics, and direct high-speed imaging of the cavitation bubble dynamics. The claw is mechanically actuated with a torsional spring and controlled by a motor. Cavitation has been successfully induced and imaged.

This year's research consisted of studying whether changing different variables (salinity, CO concentration) affects the location and formation of the cavitation bubble, as well as the speed of the ensuing shockwave.

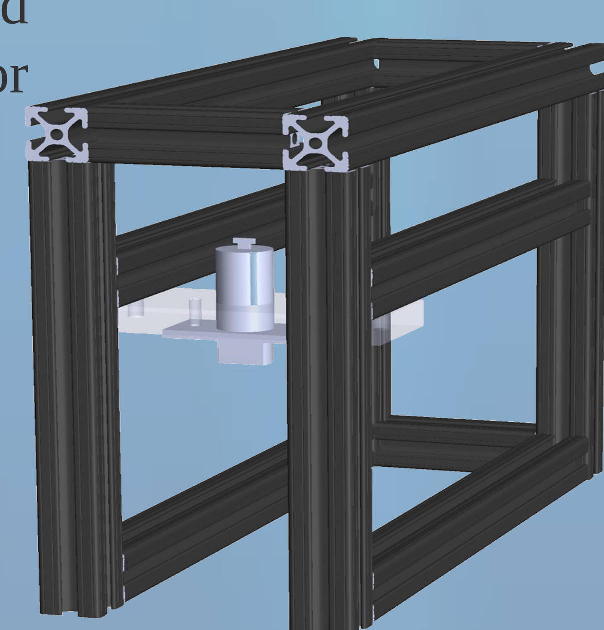
Experimental Methods

- A 14:1 scale stainless steel shrimp claw model was created
- Claw mechanism rests on base block which can be attached to base of water tank
- Acrylic side windows (not shown) are attached to the socket of the claw, forming a channel upon closure to focus a water jet away from the claw mechanism
- A removable frame was designed with an adjustable mechanism that holds the claw cocked open to a consistent angle
- A motor was used to control the release of the claw from the frame mechanism
- A Z-folded schlieren system coupled with high-speed imaging using a Phantom V711 camera was used for visualization

Mechanical Claw

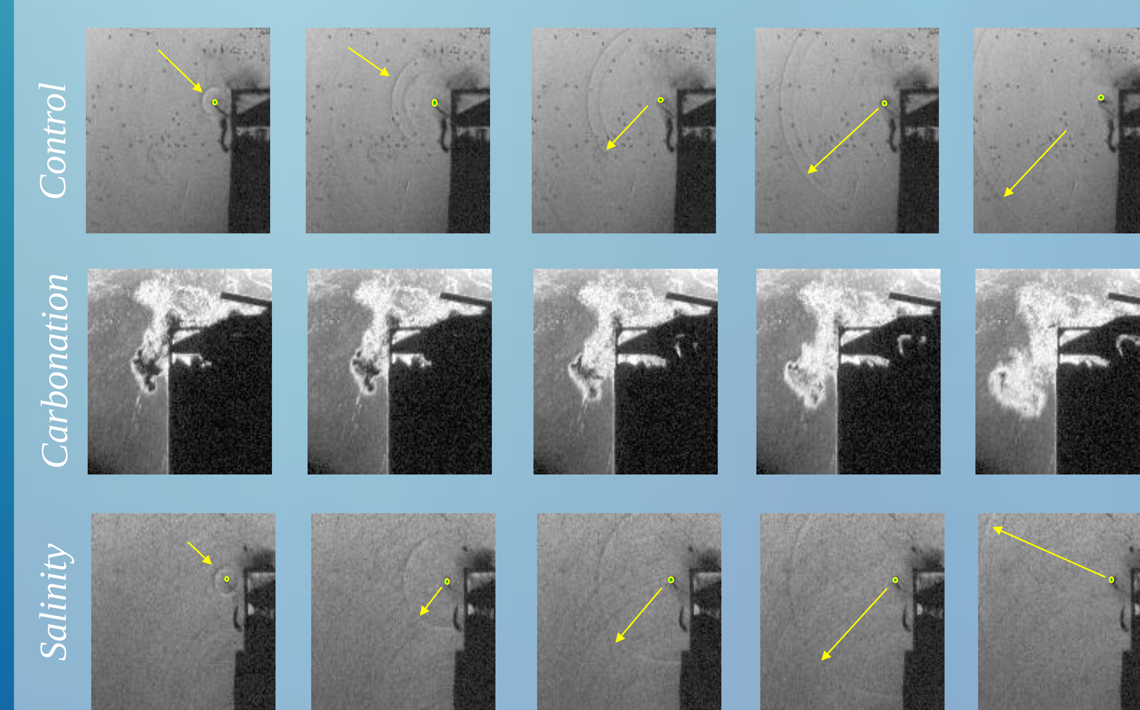


Experimental Set-up: Z-folded schlieren system and high-speed imaging



Aluminum T-slot frame with door latch

Results



Frame rate = 210.5 kfps, Frame period = 4.5 μs

Fluid Type:	Average Speed (m/s):
Room Temperature Water	1.5290 ± 0.1025
Carbonated-Water	N/A
35ppt Salt Water	1.5822 ± 0.1006

The three trials displayed were conducted with the claw set to the same starting position. The control and salt trials had a successful formation of a cavitation bubble, however the position of where the bubble formed changed for each trial (both within and between these two groups). The carbonation trials did not yield discernable cavitation bubbles or shock waves, and just created "noise" in the fluid. As seen from the images, the shock wave formation occurs just outside of the claw opening. The sequence of the images of each trial show the initial collapse of the cavitation bubble and the resulting shock wave(s).

Conclusion

The average speeds of the shock waves for the control and salinity trials are 1.5290 ± 0.1025 (×10^3 m/s) and 1.5822 ± 0.1006 (×10^3 m/s) respectively. Both of these values are above 1.484 × 10^3 m/s, the speed of sound in water, showing that both conditions yield shock waves. Carbonation in the water disrupts the homogeneity of the fluid, making it harder for a cavitation bubble to form and collapse. The data suggests that salinity slightly increases the speed, however due to uncertainty, this effect is not completely verifiable. More testing with a smaller-sized model claw and a camera with a faster frame rate should yield more illuminating results.

The results of this research indicate that it would be equally possible to purify water from fresh-water and salt-water sources with a claw-mechanism based mechanical purifier, but it would not be possible to purify more carbonated water (e.g. water from a source with a thermal vent). The purification mechanism would also not remove salt from the fluid, so it would have to be desalinated to be potable.

Acknowledgments: Professor Eliasson's Shockwave Lab, USC Viterbi Undergraduate Fabrication Laboratory, USC AME Senior Design Laboratory

Citations: [1] Smithsonian Tropical Research Institute Webpage
[2] M. Versluis, B. Schmitz, A. von der Heydt, D. Lohse, "How Snapping Shrimp Snap: Through Cavitating Bubbles," Science, Vol. 289, Issue 5487, pp. 2114-2117, DOI: 10.1126/science.289.5487.2114 (2000)