# Liquid Crystal Drop Snap-off

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## Introduction:

The goal of my summer research project, supervised by Professor David Weitz, and under the direction of Dr. Itai Cohen, was to investigate the dynamics of liquid crystals in the events leading up to and during drop snap off.

The investigation of drop snap off is important because it can be used as a mathematical model for other, more complicated events involving singularities. Liquid crystals are of interest because they can assume more structured phases than regular Newtonian fluids. This may in turn lead to unique dynamics just before and during liquid crystal drop snap off.

As a drop of fluid snaps off, the pinchoff region can be described by two radii of curvature. As shown in Figure 1, one radius lies in the drop radial plane ($\mathbf{r_1}$), and the other one lies in the drop axial plane, ($\mathbf{r_2}$). The radial plane contains a minimum radius, labeled $\mathbf{r_1} = \mathbf{h_{min}}$ in Figure 1. This minimum radius decreases as the drop approaches snap off. This decrease is then plotted against a temporal axis of time left until snap off, denoted as t*.

As liquid crystals can be very expensive, a method of testing which could conserve the fluid of interest had to be devised. A vertical liquid bridge setup, in which the fluid is confined between two flat plates was settled on for this purpose. To control the phase of the liquid crystal, a thermal bath was built. This was done using a 6 x 12 x 8 in. glass tank, 11 ft. of copper tube, and a Coherent Solid State Temperature Control unit. The copper tube was bent so that it fit into the glass tank, which was filled with distilled water, and each end of the tube was connected to the temperature control unit. The temperature control unit was then filled with distilled water, which it heated or cooled and pumped through the copper tube, thus heating or cooling the bath.

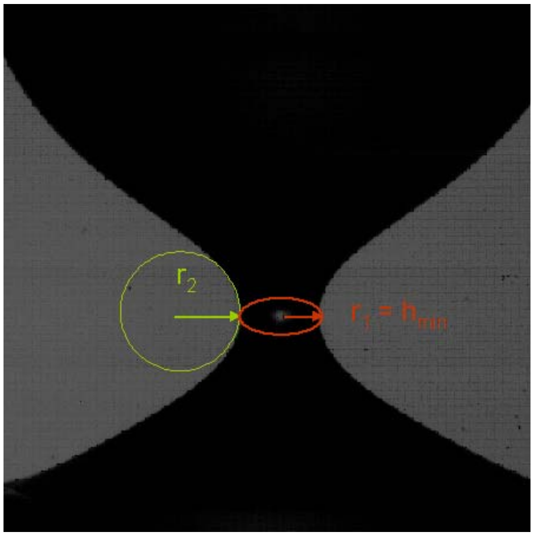


Figure 1

Next, the liquid bridge apparatus was constructed. This apparatus consisted of two 2 x 6 x ¼ in. thick plates, which formed the sides, two 4 x 6 x ¼ in. thick plates, with the centers cut out, which formed the front and back of the stand, a 2 x 4 x ¼ in. thick plate that formed the top, and a 2 x 4 x ½ in. thick plate that formed the base of the stand. These plates were tapped by hand, screwed into place and soldered together. Before soldering, a sliding plate just smaller than the top plate was fixed inside the apparatus, along with two guide rods which were soldered to the top and bottom plates, going through holes on each side of the sliding plate.

Another hole was drilled through the sliding plate so that a fine thread screw could be threaded through the sliding plate. A support rod was soldered into the base plate of the apparatus, upon which the fine thread screw rested, so that when the screw was turned, it would push off of the support rod, thus raising or lowering the sliding plate. So that the plate would slide up and down smoothly, two hollow cylinders were fastened to the underside of the sliding plate, around the guide rods. Two ½ in. diameter rods formed the ends of the liquid bridge, one fastened in the center of the underside of the sliding plate, and one fastened on top and in the center of the base plate. A 5mm diameter glass plate was then glued onto the face of each bridge rod. These glass plates served as the contact points for the fluid. The apparatus can be seen in Figure 2.

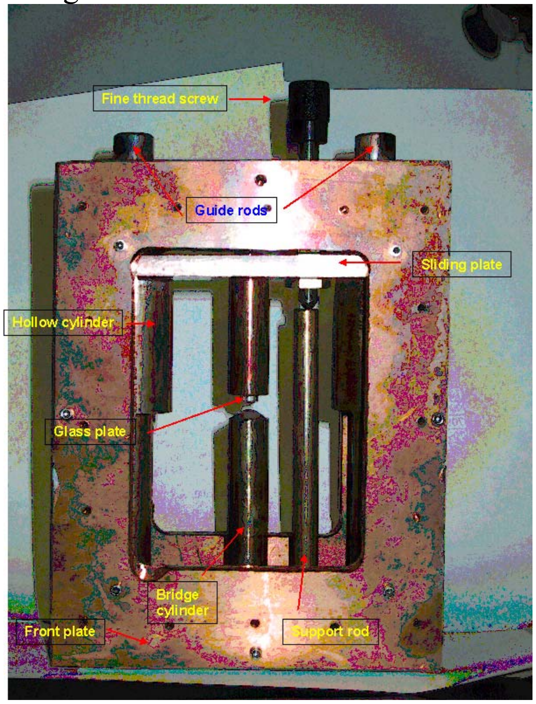


Figure 2

To make the apparatus watertight, two removable, clear acrylic plates could be screwed onto the front and back copper plates of the apparatus, with O-rings fitting between the acrylic and the copper plates, and around the holes in the centers of the copper plates.

## Experiments & Results:

Once the final apparatus was constructed, the liquid crystal 8CB could be tested on it. All 8CB samples were filmed breaking off in air at 21 degrees Celsius, in the smectic phase. First, the samples were placed on the lower glass plate. Next, the sliding copper plate was lowered until the top glass plate was wetted by the fluid, thus forming the liquid bridge drop. This drop was then slowly separated by turning the fine thread screw. Once the drop began to thin of its own accord, video recording was commenced. This means that all data was taken while the screw was no longer being turned.

Even before analysis was done, interesting dynamics were observed in the time immediately following snap off. It was seen that the two necks which formed after snap off withdrew into their respective bodies of fluid asymmetrically (Figure 3). This behavior has never been seen in any

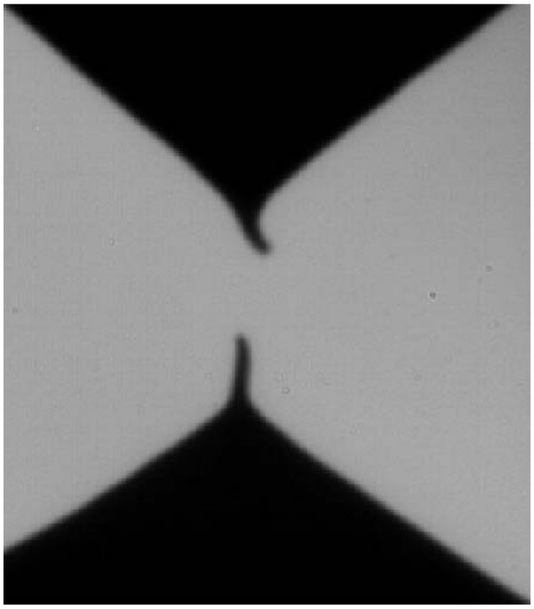


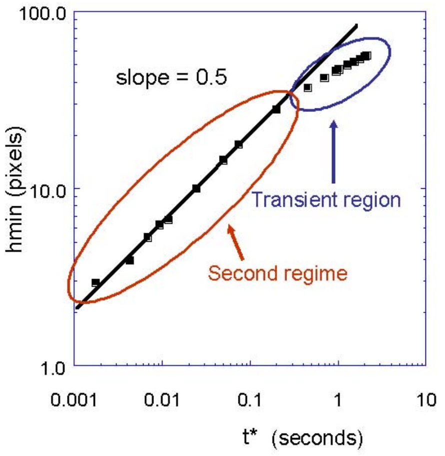
Figure 3

previous fluid snap off experiments. Once movies had been taken, they were saved and analyzed frame by frame using IDL software. A previously written profile tracking program was used to collect data. This data was used to plot the decrease of the minimum radius of the liquid bridge and the axial change in the profile against time left until snap off (denoted as t*). When a curve was fit to the plotted data (Graph 1), it was seen that, excluding the initial transients, a power law relationship of 0.5 existed between the decrease of the minimum radius and time left to snap off. This power law was seen over two full orders of magnitude on the temporal axis, and was the second, but not final, regime for the snap off process. This regime is pictured in Figure 4. The minimum radii of the profiles were then collapsed onto one another (Graph 2), and the z values at $h/h_{min}$= -3 were recorded. Analysis of these z values displayed a power law relationship of 1/3 between the decrease in z of the profile and time left to snap off (Graph 3). Neither of these two power law values have been seen in any previous drop snap off experiments.

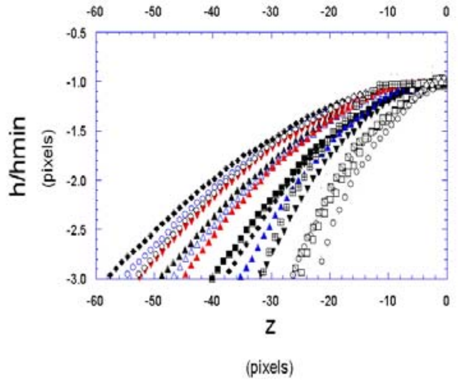
## Conclusions:

We conclude that when a liquid crystal drop breaks, it is capable of entering an asymptotic regime where the minimum radius decreases as $t^{*0.5}$ and the axial length scale decreases as $t^{*0.3}$. These scalings suggest that the liquid crystal 8CB must have other stresses in addition to the viscous stresses which govern the flows during this regime.

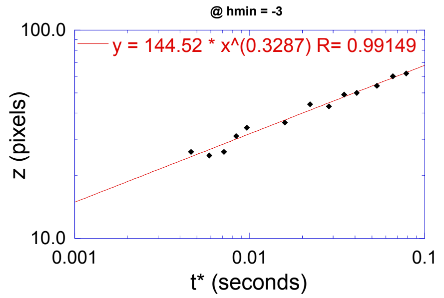
While observations were made to length scales of about 15 microns, data taken on smaller lengths scales was not as reliable. This was due to difficulties magnifying the fluid, which created error in the output of the profile tracking program. A future goal will be to collect accurate data in the final regime preceding snap off.



Graph 1



Graph 2



Graph 3

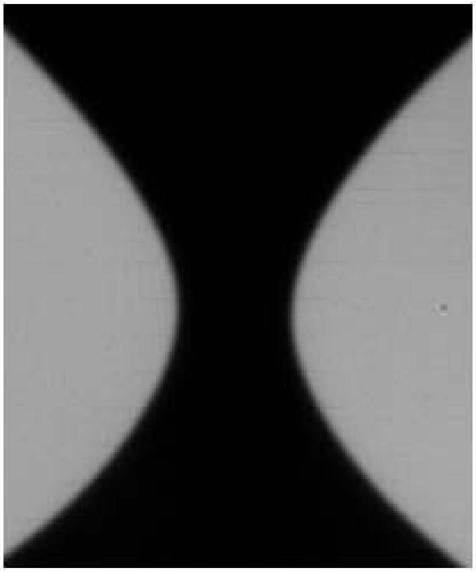


Figure 4

## References:

Itai Cohen and Sidney R. Nagel
"Testing for scaling behavior dependence on geometrical and fluid parameters in the two fluid drop snap off problem"
Phys. of Fluids, **13**, 3533 (2001).