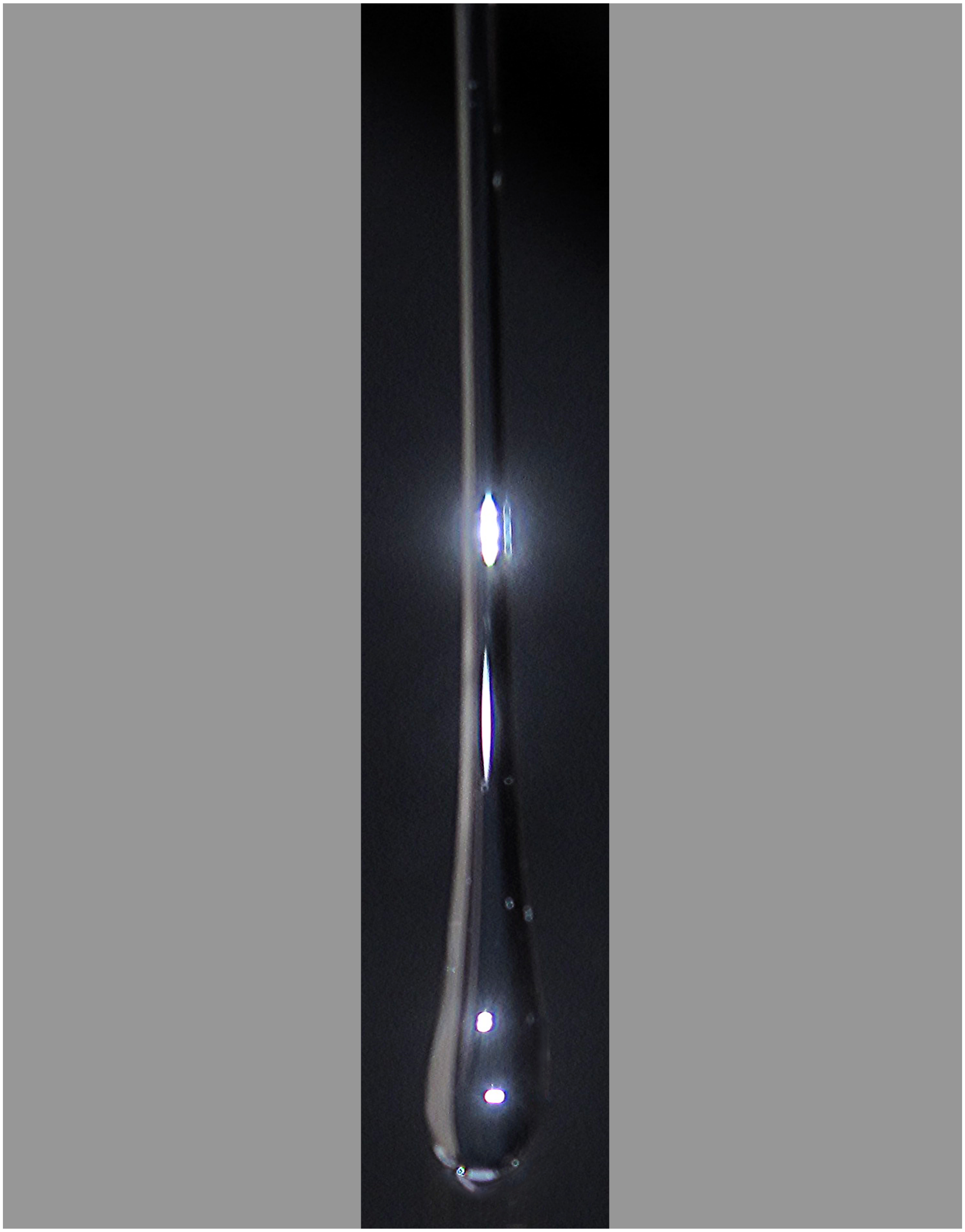
Team Project 3 – Dynamics of Saliva
Stefan Berkower. 05-4-2011. MCEN 5151.



Background:
This photograph was taken as the third team project assignment for the Flow Visualization course offered at the University of Colorado, Boulder campus. The intent of this image was to capture the flow and shape characteristics of the saliva in spit. This picture was taken with a Sony Cybershot point and shoot camera.

Experimental Setup:
The setup of this experiment for this photograph was very simple. It included a black background, a camera and myself. All lighting was due to the flash of the camera as well as some overhead lighting (see Figure 1).

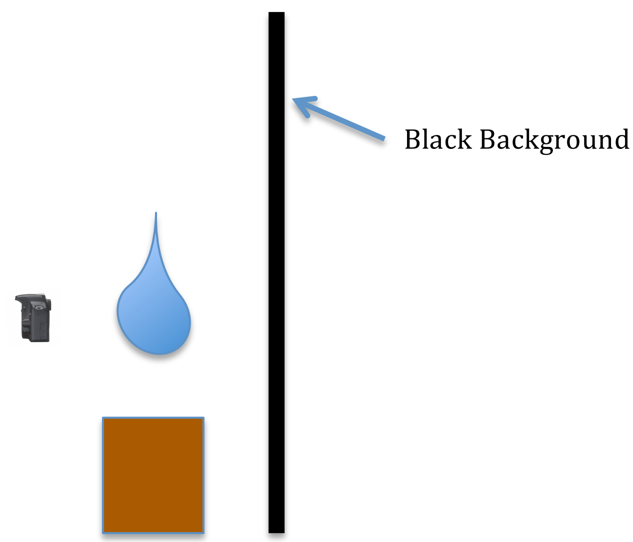


Figure 1 - Experimental Setup

I tried to capture as much of the stringing phenomenon as possible within the field of view of the camera. The camera was held approximately 3 inches from the saliva when the picture was taken. The macro setting was used with natural lighting and the following camera settings:

- F-number – 8.0
- Shutter Speed – 1/200
- Focal Length – 7.7

The photograph was taken in my bathroom at home in room temperature. The estimated length of the strand of saliva is 3 inches long (vertically) and ranging between .125 inches in diameter to .25 inches in diameter. The field of view of the cropped photograph mimics these dimensions with a slightly larger width.
The original photograph was 3156 × 3312 pixels and my bathroom wall and sink were distracting. I used Adobe Photoshop to edit this photograph by cropping the image to emphasize the phenomenon I was trying to capture. I also changed the contrast and colors to my satisfaction. The final photograph ended up a size of 1484 × 1896 pixels.

Results – Explanation of the Phenomenon:
The phenomenon that is highlighted in this phenomenon is the behavior of saliva as it falls due to gravity. Saliva itself exhibits material properties very similar to that of water a low viscosity liquid[i], yet its physical behavior suggests that something else is occurring to give it an elastic and viscous feel. A recent study[ii] completed at the University of Purdue in Indiana suggests that saliva, while exhibiting some characteristics of a non-newtonian fluid; it more so exhibits the characteristics of a viscoelastic fluid. In this article Pradeep Bhat and his associates investigated at what levels of viscoelasticity beading would form along the string of the fluid. They suggest that there are two critical non dimensional numbers that can account for different levels of beading (from no beading to multiple beads). These two numbers are the Ohnesorge number and the Deborah number. The Ohnesorge number is defined as the ratio of viscous, t_v, to internal forces, t_c (equation 1) and the Deborah number is represented as the ratio between the relaxation time of the polymer (λ) to the characteristic time – the dominant value in the Ohnesorge number (equation 2).

$$Oh = \frac{t_v}{t_c} \quad (1)$$

$$De = \frac{\lambda}{t} \quad (2)$$

In this same study[ii] they looked at a wide variety of combinations of these two fluid characteristics – anywhere from saliva (Figure 2) to water-soluble polymers (Figure 3).

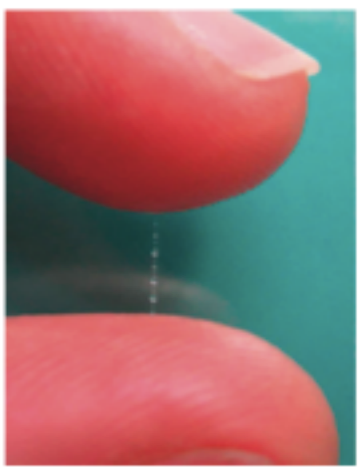


Figure 2 - Beading of Saliva

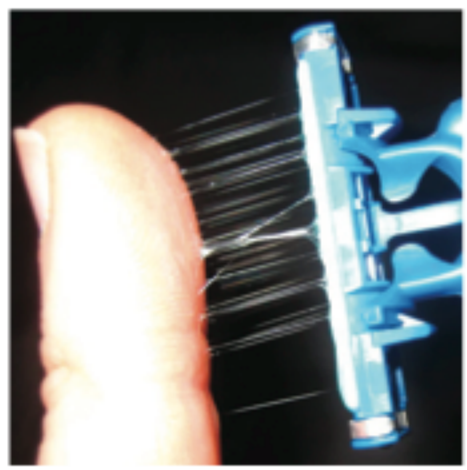


Figure 3 - Beading of water-soluble polymer

After a thorough investigation of these properties they were able to generate a plot showing the general trends associated with various combinations. This plot is shown below in Figure 4 and is used to try and determine the specific characteristic of my saliva flow.

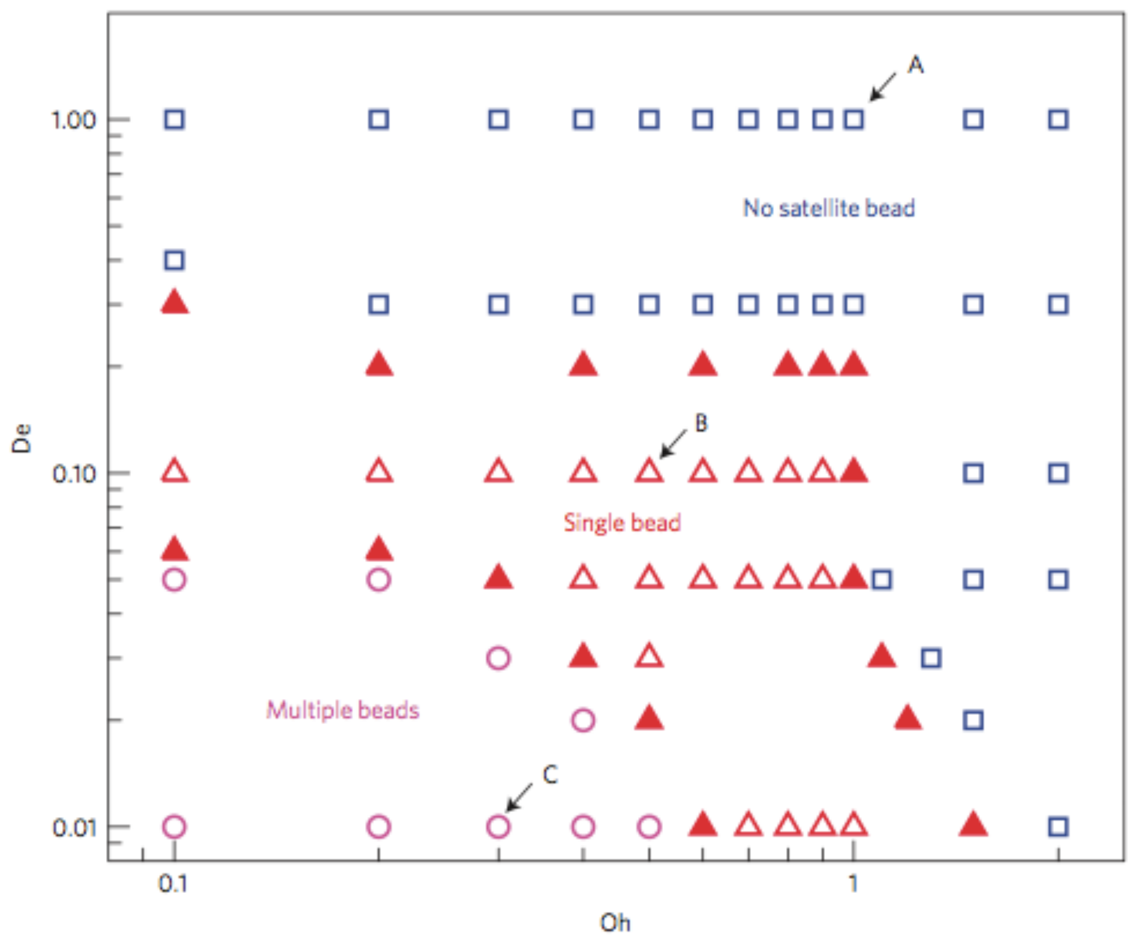


Figure 4 - Plot of Deborah Number versus Ohnesorge Number and their respective beading characteristics

In my image no beading was occurring at any point except for the very bottom where a large bead was forming. I was drinking a lot of water at the time to try and increase the amount of saliva that I was able to spit out; this could have caused a slight dilution of my saliva this would effectively decrease my viscous forces and increase my polymer relaxation time (the time for the polymer to reach a point where it can stretch no more). This would put my image of saliva in the top left corner of the plot in Figure 4, corresponding to a no beading scenario. This also suggests that my saliva is currently exhibiting characteristics more similar to a non-newtonian fluid; at a point the stretching can no longer occur and the strand is broken suddenly, rather than beginning to form beads.

Discussion, Conclusion and Future Work:

The physics of saliva and similar bodily fluids are a generally not very well understood in literature, but can have many benefits. Understanding the composition and behavior of these substances can be extremely useful in many applications anywhere from improved ink jet printing to nano-fiber technology to personalized medicine[iii]. Further research is currently being completed and the understanding in the subject will soon be greatly improved.

Future work for this photograph would include trying to capture more instances of viscoelastic/non-newtonian fluids and how there characteristics compare to the findings in the previously mentioned study.

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[i] R. Nave. Hyperphysics, Georgia State University. (2010). http://hyperphysics.phy-astr.gsu.edu/hbase/surten.html (Accessed 5/01/2011)
[ii] P. Bhat, S. Appathural, M. Harris. *Formation of beads-on-a-string structures during break-up of viscoelastic filaments*. Nature Physics (June 6th, 2010).
[iii] J. Boyd. Insciences organization. *Answer to Saliva Mystery Has Practical Impact* (2010). < http://insciences.org/article.php?article_id=9144>