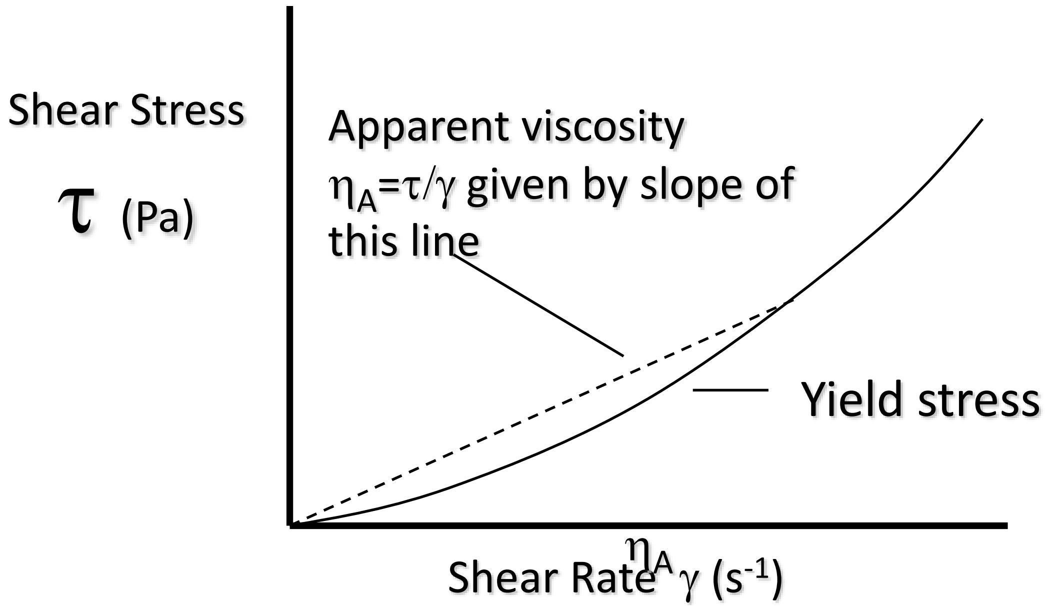
Non-Newtonian Intro

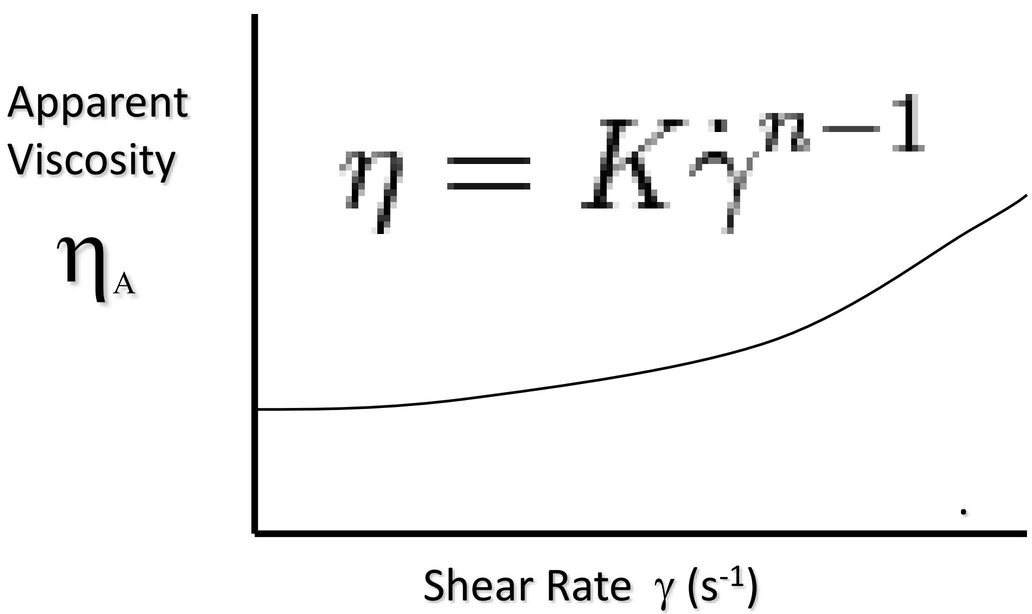
- *Dilatant (shear thickening):* Increasing shear force gives a less than proportional increase in shear rate; the material "seems" to be more viscous at higher shear rates.
- Dilatant food systems are not common.
- Examples are some cooked starch suspensions.

Photo by Alan Rees

Wet starch at 40-70% solids = 1.5 – 2.5 Volume ratio



Shear Stress
τ (Pa)
Apparent viscosity
η_A=τ/γ given by slope of this line
Yield stress
η_A
Shear Rate γ (s-1)



Apparent Viscosity
η_A
$$\eta = K\dot{\gamma}^{n-1}$$
Shear Rate γ (s-1)

Cornstarch Properties

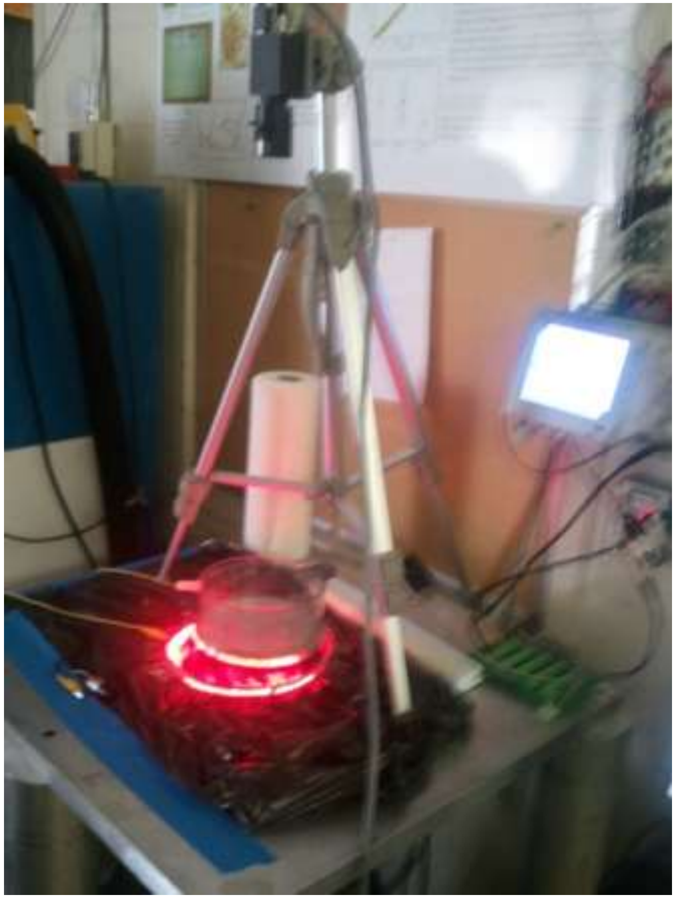
- Coined by Dr. Suess as Oobleck
- Typically mixed at a 1.5:1 – 2.5:1 Starch to Water Ratio.
- Density of 540 g/cm^3
- Very well known for the formation of holes and starches

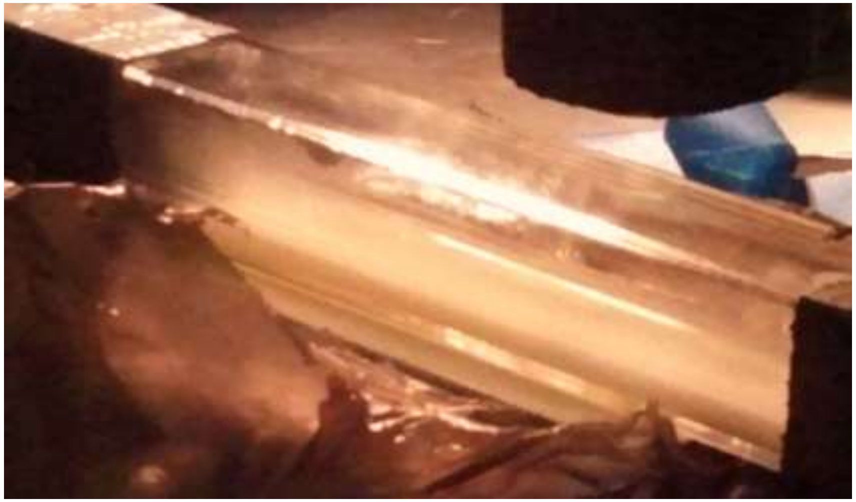
Objectives

- Primary Goals:
  - Measure and observe the similarities between the Non-Newtonian Faraday Waves and the Driving Signal Wave (eg. They share similar parent functions)
  - Observe the phenomena of holes and balloons (aka fingers)
  - Compare the bifurcation of the Non-Newtonian to the Newtonian.
- Secondary Goals:
  - Understand better the relationship between Concentration and Onset of Faraday Waves

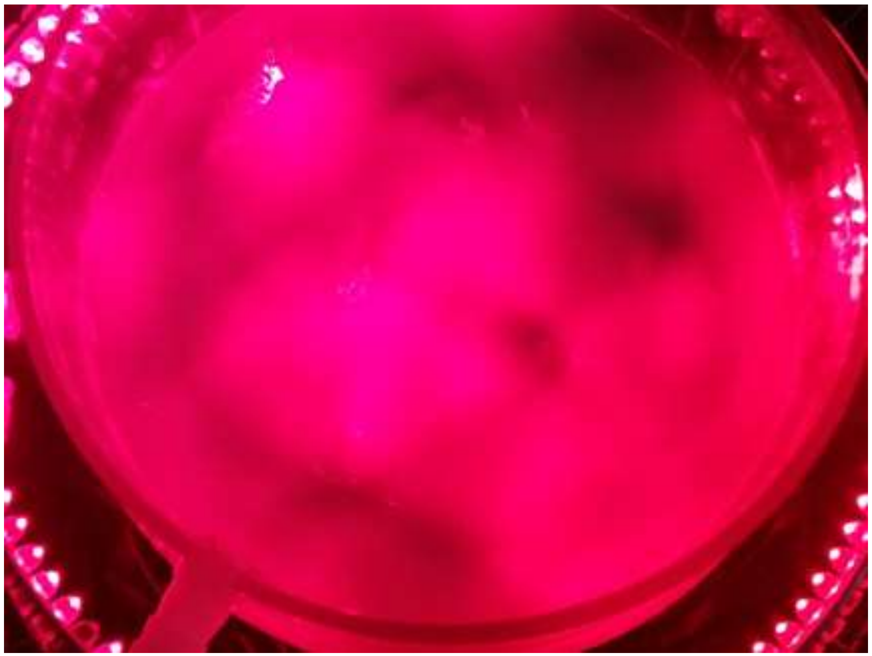
Setup: Making Oobleck

Setup





Attempt 1 Cornstarch at 1.5:1 Ratio

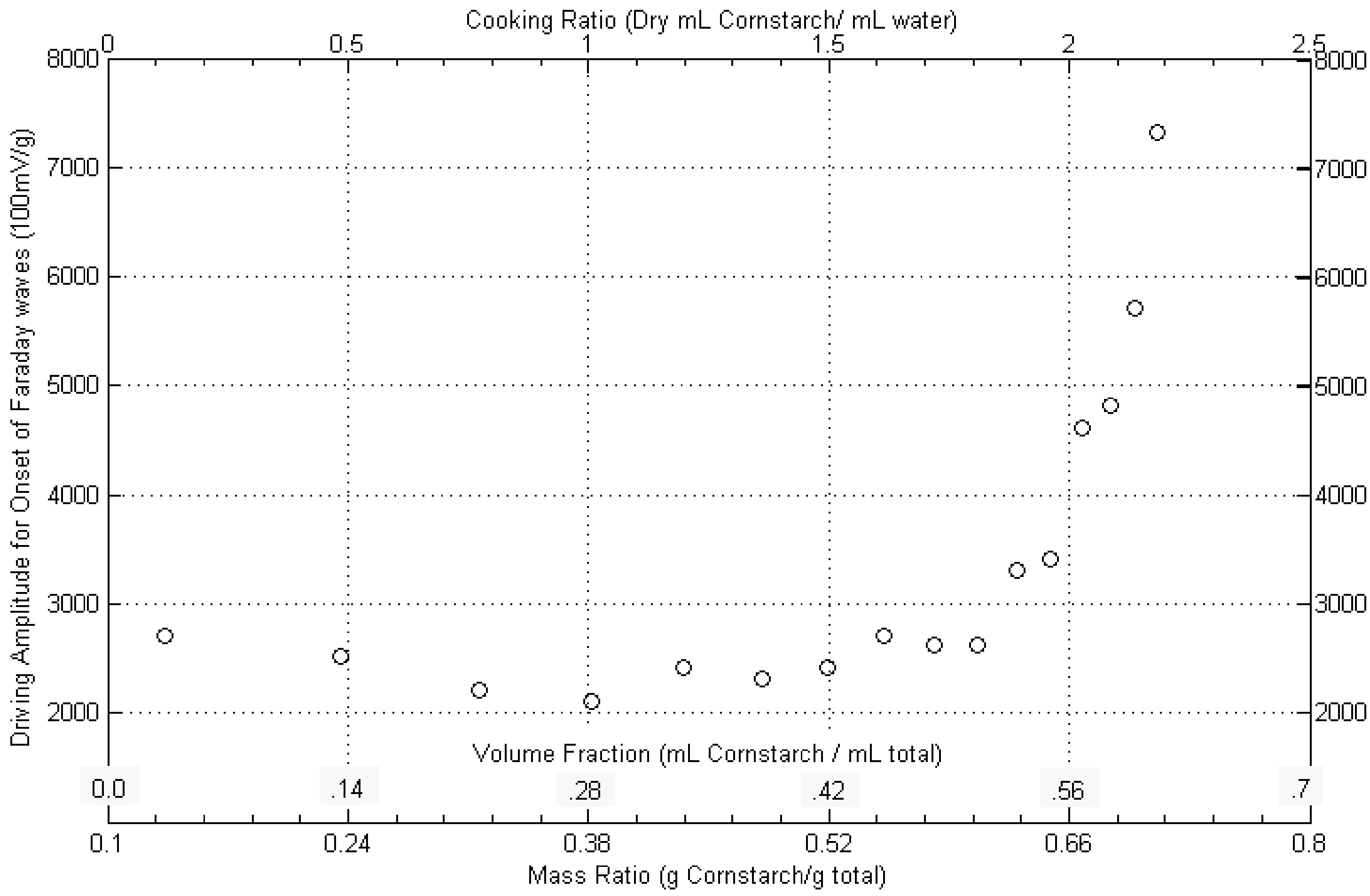


Its appeared too Newtonian
So we used 2.5:1 instead

Results Video 01

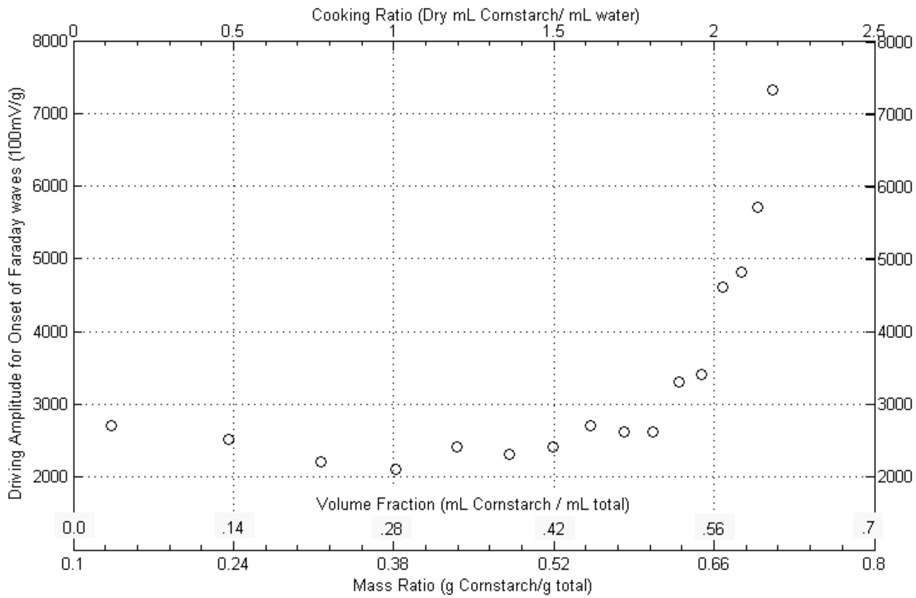
http://youtu.be/M_qXzyaIKI4

Results: Concentration vs. Amplitude



Results: Concentration vs. Amplitude

$$\eta = K\dot{\gamma}^{n-1}$$



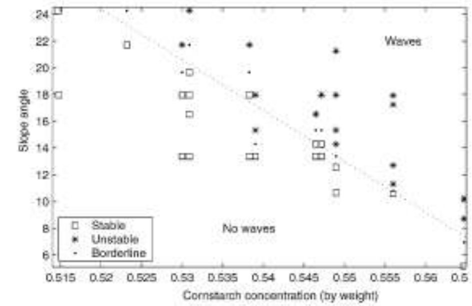


Fig. 2. Flows with and without unstable roll waves, plotted on a graph of slope angle against concentration (fraction of cornstarch by weight). The stars show flows in which waves appeared to amplify as they propagated downstream, the squares represent flows in which the waves appeared to decay. The dotted line indicates the best-fit border between stable and unstable flows.

Balmforth, et. al 2005.

354 BARNES

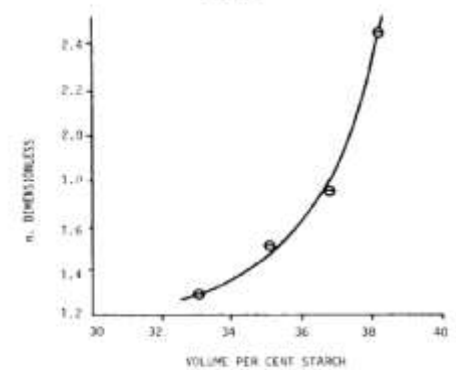


Fig. 13. Redrawn from Griskey and Green.[35] Power-law index as a function of phase volume for a starch suspension.

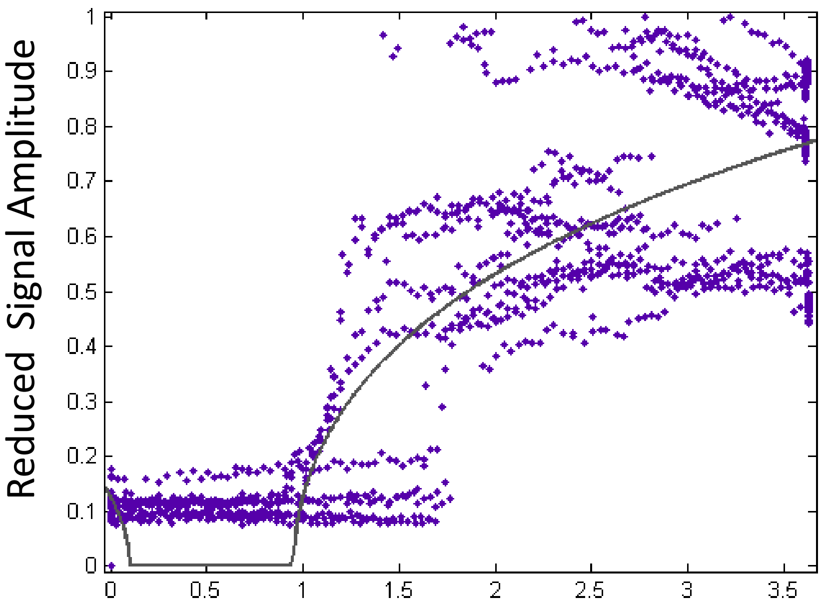
Griskey and Green 1968

Video on Cornstarch at 40 Hz

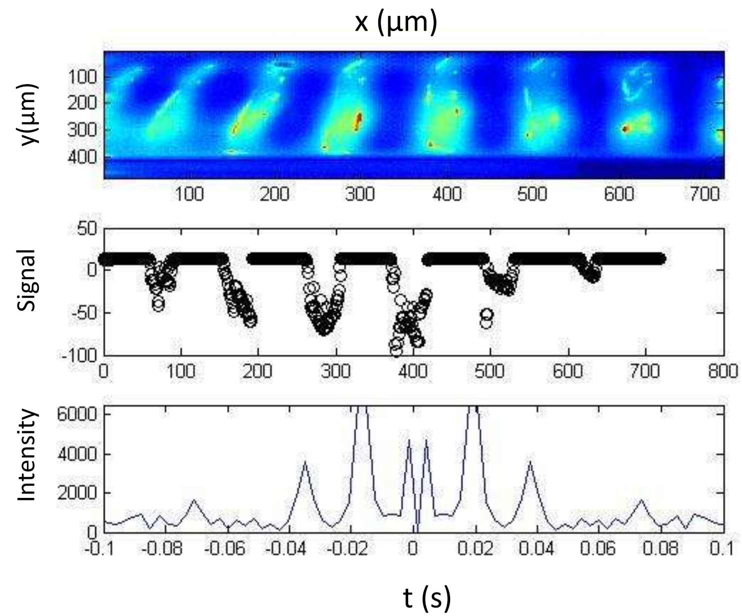
http://www.youtube.com/watch?v=IVxmY0CDF5g

Corn Starch 40 Hz

Bifurcation Diagram for 40 Hz



Driving Acceleration (a) (100 mV/g)



$$Amplitude = A(a) = \sqrt{-\frac{G}{2K} + \sqrt{\frac{G^2}{4K^2} + \frac{a}{K} - \frac{h}{K}}}$$

$$\frac{h}{K} = .1 \;\; for\; 40\; Hz$$

Psuedo-model
Based on Strogatz 3.6.6

$\frac{\omega - \omega_0}{K}$

Cornstarch at 60 vs. 100 Hz

- Wave Number k increases as the driving frequency ω increases
- The area of cornstarch that undergoes observable Faraday wave oscillations increases with frequency driving frequency

$\frac{\omega - \omega_0}{K}$

Conclusion Bifurcation for Corn starch