

Shear Jamming in Cornstarch

by John Parker

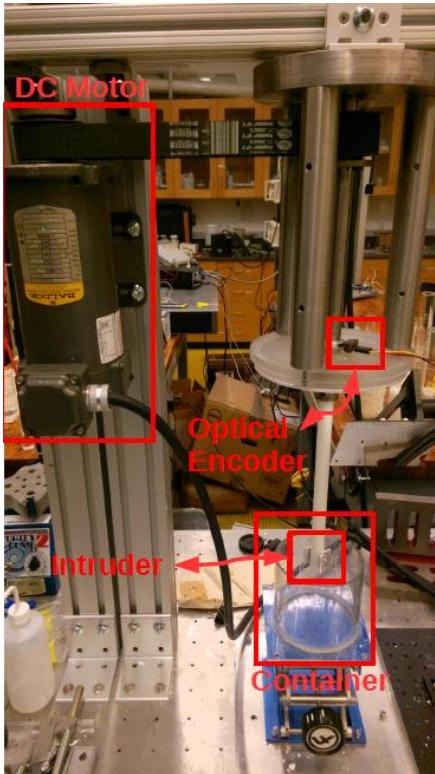


Figure 2: Experimental setup, with major components labeled.

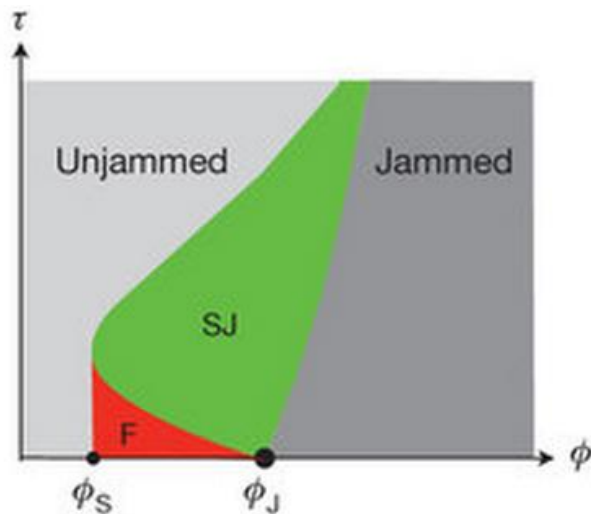


Figure 1: Phase space diagram of a granular material. An unjammed state becomes jammed by increasing the packing fraction or applying a shear.¹

$$\phi = \frac{V_{\text{cornstarch}}}{V_{\text{cornstarch}} + V_{\text{water}}}$$

Granular materials and dense suspensions, such as cornstarch and water, have the interesting property that, under some conditions, they behave like a liquid, while at other times they behave like a solid. This transition is known as jamming.

One way of inducing the jamming transition is by compression. This is well understood in terms of grains being pushed together and forming large force chain networks.

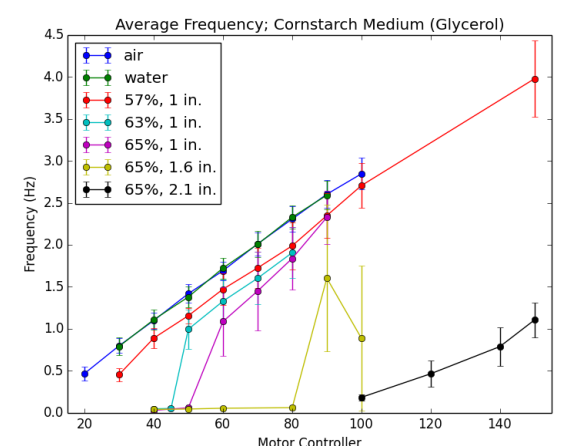
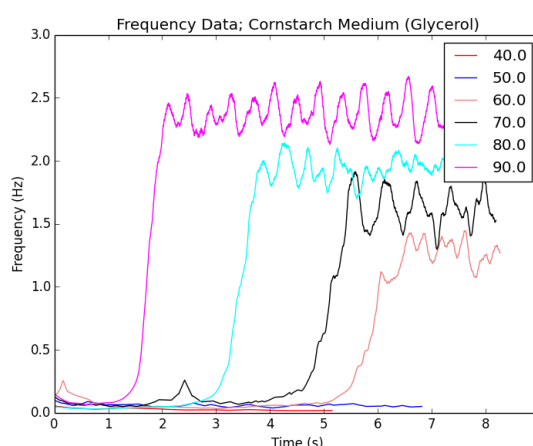
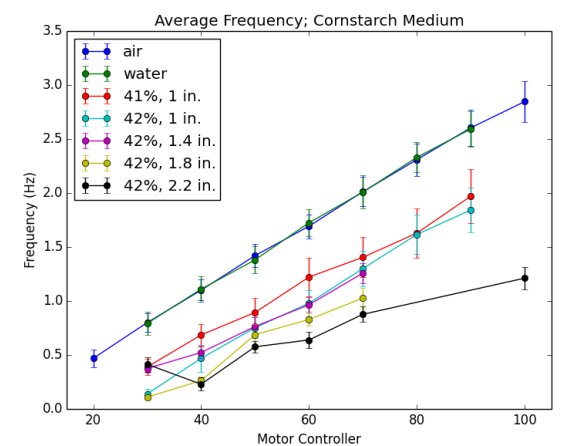
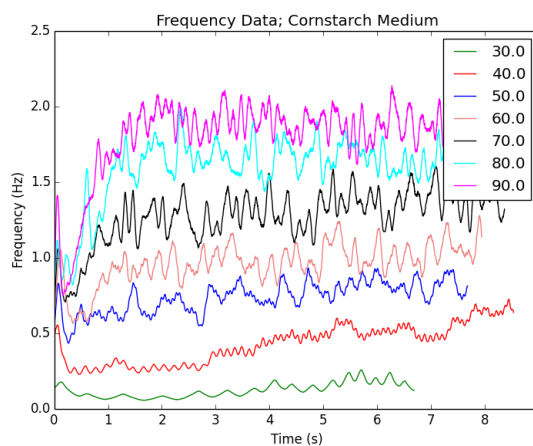
The transition can also be induced by a volume-preserving shear stress. This is more unusual, as no compression is involved, and yet force chain networks show up again. Figure 1 shows a theoretical phase diagram of these systems.

Jamming – the liquid-solid transition

The response of the suspension to a given shear stress determines whether it is solid-like and its strength. The response is taken to be the frequency of an intruding object.

The frequency data in a cornstarch suspension increases with increasing stress (labeled 30-90). The build-up in frequency takes longer as stress increases, indicating a large stress response on the intruder. This is a sign of a transition to a solid state.

When glycerol is added to the suspension, the viscosity greatly increases and the effect becomes more profound. The build-up occurs very quickly after some onset time, before which the intruder is stuck. The onset time also coincides with the formation of a crack.



Cracking – breaking the solid state

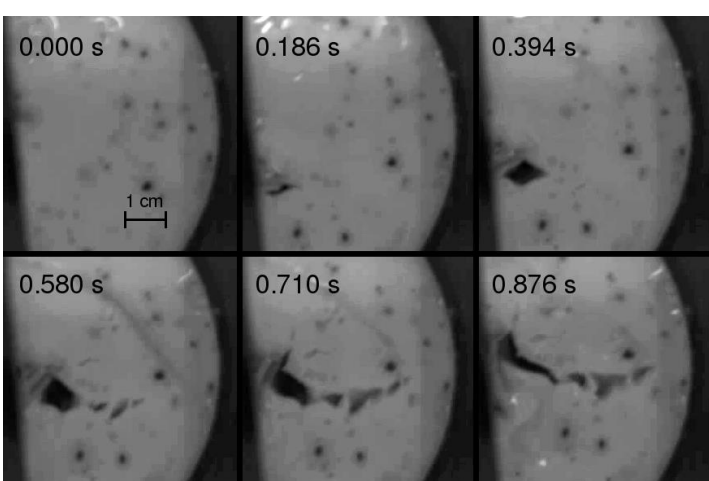
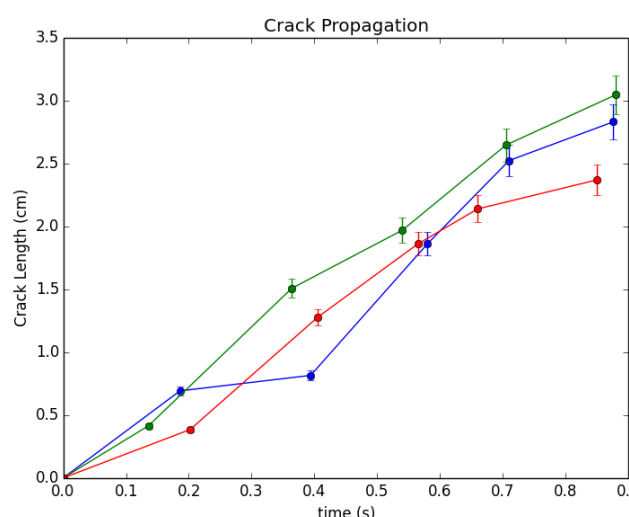


Figure 3: The formation of a crack in a cornstarch suspension. For this run, $\phi = 0.63$.



Under enough stress, the solid phase of the cornstarch medium can form cracks, a property unknown to liquids. One such crack is depicted in Figure 3.

The crack propagates out to a length of 3 cm, at about a constant speed of 3 cm/s.