Team Second

Curtis Dunford
ATLS / MCEN - 4151-001
Dr. Sunberg
Nov 01, 2025
CU Boulder College of Engineering

Figure 1: Still extracted from slow motion video.

Abstract

For Team Second, our group examined the shear thickening behavior of a cornstarch–water suspension "Oobleck" as it transitioned between liquid and solid under stirring. We added our own color of glitter particles to act as tracers to help observe the flow. Our mixture was filmed under controlled lighting from the bottom of the screen to highlight dynamic texture changes on the fluid surface. As the Oobleck was stirred, we observed localized jamming, surface fracture, and rapid recoil followed by slow relaxation, producing distinct patterns of flow and stasis. By tuning the consistency, lighting, and stirring rate of the mixture, we captured how shear transforms an everyday fluid into a vivid display of viscoelastic structure and motion.

Experimental Setup and Methods

We prepared oobleck at roughly a 2:1 cornstarch:water mass ratio. We then added about fifteen percent glitter by mass relative to the base mixture, bringing the total solids to about 70 percent by mass. After mixing, we poured into a 60 mm Petri dish to a uniform depth and allowed the sample to relax to a quiescent state.

To excite shear-thickening behavior in a controlled way, we applied rotational forcing with a wooden stir stick, approximately one quarter of an inch wide. We inserted the stick near the free surface and swept it through gentle circular paths to impose azimuthal shear, then stopped the motion abruptly to capture the relaxation. The rotation produced a radial velocity gradient and the glitter tracers revealed transient jamming fronts. After each forcing interval, we waited for the flow to decay before repeating the sequence, so each trial began from nearly the same initial condition.

Imaging Setup and Post Processing

We worked in the Project Depot on campus. The 60 mm Petri dish sat fastened to the face of an adjustable color light source, to provide clean transmitted light and strong contrast for tracer motion. We positioned the camera at dish height for a side view to read near-surface texture. We recorded in Full HD at 120 fps on a Canon EOS R50 with the RF 50 mm macro lens. Focus was set manually at the interface, and exposure favored depth of field while keeping ISO low enough to preserve fine particle detail. Post-processing was done in Adobe Express with small contrast and timing adjustments. The final cut uses the Adobe Express stock track "Inspiring Trip Hop Is."

Physical Phenomena

We studied a dense cornstarch-water suspension through direct, hands-on interaction and slow-motion video analysis. Without a rheometer, we relied on touch, sight, and time-resolved imaging to observe how the system responds under localized, intentional shear. This was not a controlled torque test; it was an exploration of a living, reactive material. And yet, the physical phenomena that emerged were striking and consistent with known theories of shear thickening and jamming [1][2][3].

Initially, the mixture slumped under its own weight, behaving like a heavy, sluggish liquid. But when we introduced a directional force with a wooden stick, especially at higher speeds or sharper angles, the system pushed back. The resistance was not linear. There was a distinct moment—felt in the hand and seen in the frames—where the fluid stiffened, and a solid-like region emerged around the point of impact. Glitter particles suspended at the surface were swept outward along a curved boundary, which propagated as a visual jamming front [3][4].

This was not a gradual process. It was sudden, almost binary. The fluid would flow, then arrest. In that instant, the cornstarch particles were no longer simply suspended; they were in contact, locked into a frictional network that resisted deformation. This is the essential picture behind discontinuous shear thickening (DST) in dense, non-Brownian suspensions near the jamming threshold [1][2].

Because we could not measure absolute stress or strain rate, we approached the flow behavior locally. In segments of relatively uniform motion, we estimated apparent viscosity $\eta_{\text{app}} = \tau/\dot{\gamma}$ using time between frames and tool displacement. When the data permitted, we extracted local slopes:

$$n_{\text{local}} = \frac{d \ln \tau}{d \ln \dot{\gamma}}$$

A value of $n > 1$ indicated shear thickening in that interval. When helpful, we reported power-law forms like $\tau \sim \dot{\gamma}^{n_{\text{local}}}$ over short segments, but made no claim to global constitutive laws. These fits were compact summaries of local behavior [1].

Example: Estimated shear rate and local slope from video. One segment showed a 120° sweep of the stir stick in 5.85 seconds, with a tool radius of approximately 45 mm. Assuming the stick traced an arc of $\theta = 2\pi/3$ radians, we estimated angular velocity:

$$\omega = \frac{\theta}{t} = \frac{2\pi/3}{5.85} \approx 0.358 \text{ rad/s}$$

$$v = \omega r = 0.358 \times 0.045 = 0.0161 \text{ m/s} = 16.1 \text{ mm/s}$$

Assuming a fluid depth $h \approx 6$ mm, the approximate local shear rate was:

$$\dot{\gamma} \approx \frac{v}{h} = \frac{16.1}{6} \approx 2.68 \text{ s}^{-1}$$

In faster trials, with Δt nearly halved, $\dot{\gamma}$ exceeded 5 s^{-1}, and the resistance increased significantly—suggesting a local power-law slope $n_{\text{local}} > 1$ and thus shear thickening behavior.

To explain the abruptness of the transition, we referenced the Wyart–Cates model: a stress-dependent shift from lubricated to frictional contact networks [2]. As stress exceeds a threshold $\sigma^\star$, lubrication films collapse and the material behaves as if its jamming volume fraction ϕ_J has decreased. The system jams earlier than it would under purely viscous flow. Mathematically, the model defines:

$$\phi_J(\sigma) = f(\sigma)\, \phi_J^{\mu} + [1 - f(\sigma)]\ \phi_J^0$$

and

$$\eta(\phi, \sigma) = \eta_0 \left[1 - \frac{\phi}{\phi_J(\sigma)}\right]^{-2}$$

This framework helped us interpret what we saw: the moment of jamming was not arbitrary; it was a stress-driven transition in particle interactions [2].

When driven rapidly, we witnessed full dynamic jamming fronts—regions of the fluid that visibly transitioned into solid under the tool and expanded radially as the motion continued. These fronts pushed surface glitter like snowplows and left a wrinkled, temporarily arrested core behind. The visuals matched previous high-speed studies of impact-activated jamming [3][4]. Even without direct force measurement, the asymmetric front propagation and glitter displacement confirmed that force was transmitted ahead of the driver.

Conclusion

My team and I explored the behavior of oobleck through a series of improvised, hands-on visual experiments and had a great time doing it. Each of us approached the material differently: Cooper launched a rubber band into his sample to trigger rapid impact responses; Isaac stirred colored dye to trace internal mixing and slow relaxation; I focused on jamming fronts and glitter tracking under stick-driven shear. These varied experiments gave us different windows into the same underlying physics.

Other visual clues supported our interpretation. Gentle stirring left the surface smooth and reflective; sudden impacts fractured it. Slow pulls caused the fluid to cling and stretch, while fast pulls yanked up entire chunks of jammed suspension. The material oscillated between liquid and solid depending on how it was touched. These behaviors were highly path-dependent, consistent with confinement-sensitive transitions and re-entrant solidification as described in earlier rheological studies [5].

In the end, even without formal instrumentation, we uncovered complex and consistent behavior using only light, motion, and intuition. I would like to mention that I did use Kinovea tracking software to extract angular speed using superimposed geometry.[7] Our observations were physically rich and aligned with modern theories of discontinuous shear thickening and dynamic jamming. Flow visualization helped us turn simple interactions into meaningful insight [6].

References

E. Brown and H. M. Jaeger, "Shear thickening in concentrated suspensions: phenomenology, mechanisms and relations to jamming," *Reports on Progress in Physics*, vol. 77, no. 4, 046602, 2014. https://ericbrownlabs.org/BJ14_RoPP.pdf

M. Wyart and M. E. Cates, "Discontinuous shear thickening without inertia in dense non-Brownian suspensions," *Physical Review Letters*, vol. 112, no. 9, 098302, 2014. https://link.aps.org/doi/10.1103/PhysRevLett.112.098302

S. R. Waitukaitis and H. M. Jaeger, "Impact-activated solidification of dense suspensions via dynamic jamming fronts," *Nature*, vol. 487, pp. 205–209, 2012. https://www.nature.com/articles/nature11187

I. R. Peters and H. M. Jaeger, "Quasi-2D dynamic jamming in cornstarch suspensions: visualization and force measurements," *Soft Matter*, vol. 10, pp. 6564–6570, 2014. https://pubs.rsc.org/en/content/articlelanding/2014/sm/c4sm00838c

A. Fall, N. Huang, F. Bertrand, G. Ovarlez, and D. Bonn, "Shear thickening of cornstarch suspensions as a re-entrant jamming transition," *Physical Review Letters*, vol. 100, no. 1, 018301, 2008. https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.100.018301

Flow Visualization Course, "FlowVis.org – The Physics and Art of Fluid Flow," University of Colorado Boulder, 2025. https://www.flowvis.org/.

Dunford, Curtis. *Team Second*. Vimeo, 22 Oct. 2025. https://vimeo.com/1129708848?fl=ip&fe=ec.

OpenAI, "ChatGPT," Nov. 2025, accessed via chat.openai.com. Based on the GPT-4 architecture. https://openai.com/chatgpt

Kinovea Team, "Kinovea — Free 2D motion analysis software," version 0.9.5 (or latest), https://www.kinovea.org/

Additional Images Shot During Flow Visualization and Post Processing

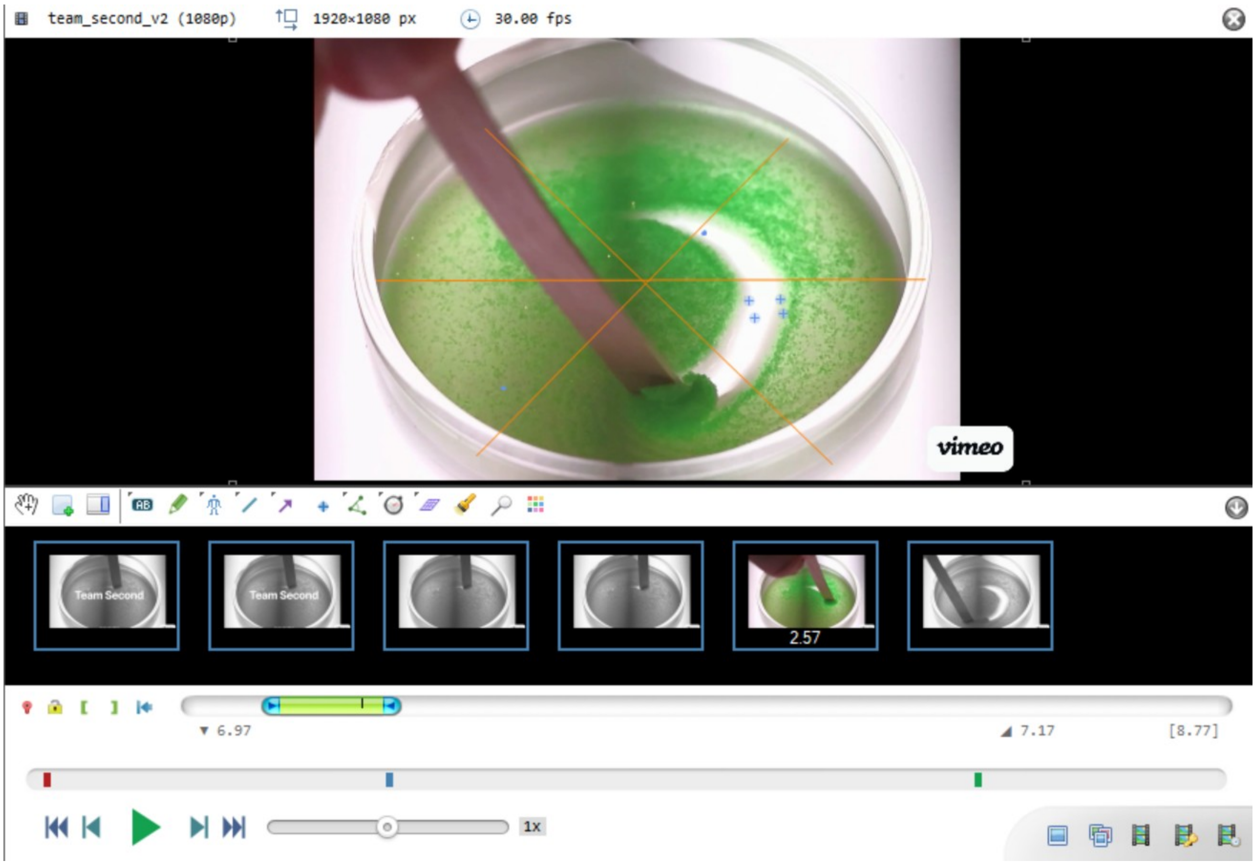

Figure 2: Particle tracking for omega using Kinovea