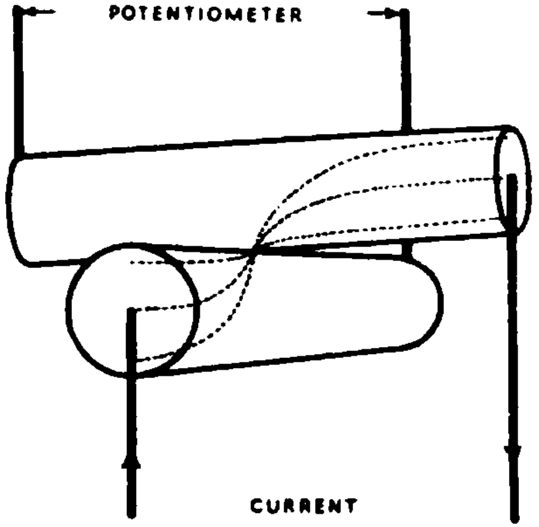
ME 412:

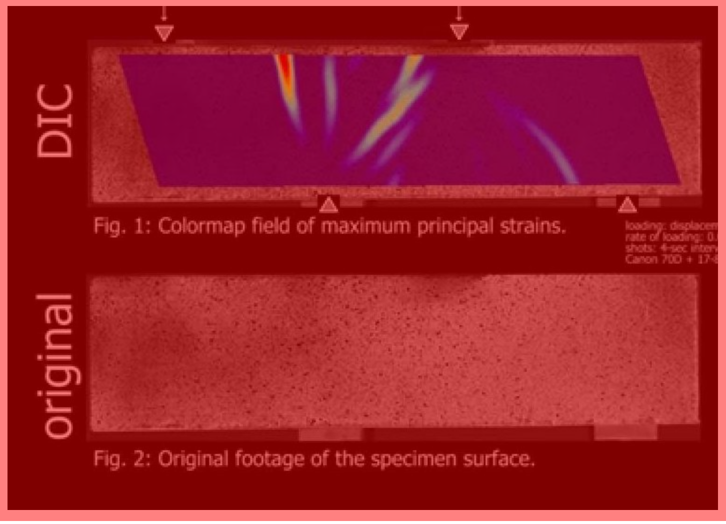
Experimental Methods in Engineering Mechanics

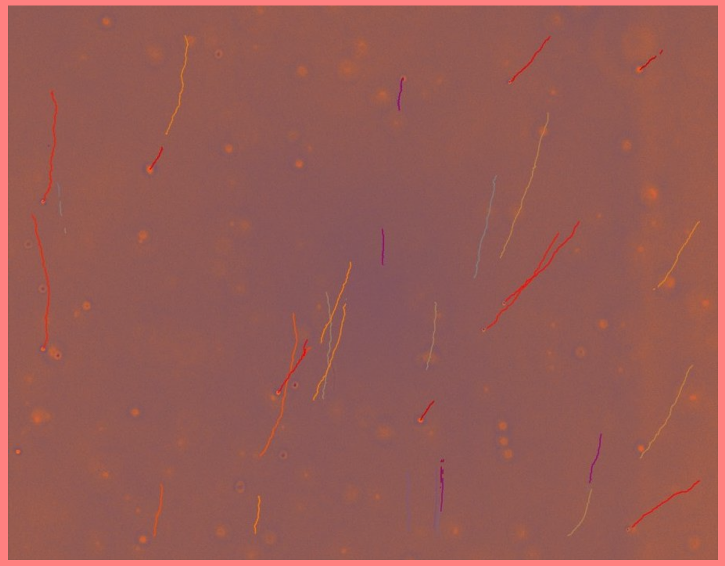
John M. Kolinski

PATT - EMSI

18.9.2019







Grades & assessments in brief

- Each student will share an overleaf project of their ongoing lab notebook. The lab notebook is an essential part of scientific activity, and should record relevant details sufficient to reproduce any reported experiment. Clarity of exposition, figure presentation and captioning, and rigor are all key components to the lab notebook.

- The report on the final measurement will follow the format of a PRL paper (see following slide)

Lab report format

PHYSICAL REVIEW LETTERS **123,** 128001 (2019)

Editors' Suggestion | Featured in Physics

Using Acoustic Perturbations to Dynamically Tune Shear Thickening in Colloidal Suspensions

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(Received 16 May 2019; published 17 September 2019)

Colloidal suspensions in industrial processes often exhibit shear thickening that is difficult to control actively. Here, we use piezoelectric transducers to apply acoustic perturbations to dynamically tune the suspension viscosity in the shear-thickening regime. We attribute the mechanism of dethickening to the disruption of shear-induced force chains via perturbations that are large relative to the particle roughness scale. The ease with which this technique can be adapted to various flow geometries makes it a powerful tool for actively controlling suspension flow properties and investigating system dynamics.

DOI: 10.1103/PhysRevLett.123.128001

The orders-of-magnitude increase in viscosity that arises under high shear makes dense suspensions ideal for numerous industrial applications including shock absorption, damping, soft-body armor, astronaut suits, and curved-surface polishing [1–6]. The challenge in using such shear thickening fluids, however, is that this same increase in viscosity can lead to jamming and failure of pumping and mixing equipment driving the flows. The ability to manage these limitations of this important technological material remains challenging [1,7] because

Here, we determine whether externally applied acoustic perturbations can be used to actively tune the suspension viscosity in the shear thickening regime. The advantage of this approach is that acoustic perturbations can controllably manipulate particles [36–43] and can be applied via readily available piezoelectric transducers that are bonded to otherwise fixed surfaces [40,44,45]. The key principle motivating our work is that nanoscale acoustic disturbances will locally perturb particles and break the force chains

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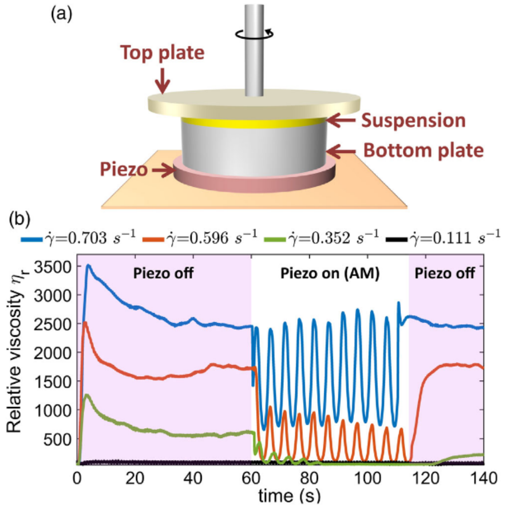


FIG. 3. Experimental setup and AM measurements. (a) The schematic of the acoustic-rheometer setup. The top plate is connected to the rheometer and the bottom plate is bonded to the piezoelectric element. The suspension is confined between the two plates. (b) The instantaneous viscosity response of $\phi = 0.53$ suspension to the gradient-direction perturbations at representative strain rates. The relative viscosity is defined as the ratio of the suspension viscosity to the solvent (dipropylene glycol, 0.11 Pa s) viscosity. Each measurement is performed at a steady $\dot\gamma$ for 140 s in which the AM signal is turned on at time $t \sim 60$ s for at least nine modulation cycles, followed by an off-period for the remaining time. Measurements for $\phi = 0.50$ suspension are shown in Supplemental Material, Fig. S4 [50].

For strain rates corresponding to the transition regime between the Newtonian and fully thickened state ($\dot\gamma = 0.596$, $0.352\ s^{-1}$), the acoustic perturbations are sufficient to dethicken the suspension viscosity to the value in the Newtonian regime. Interestingly, the maximum viscosity during the time when AM perturbations are applied does not recover fully to the steady state value. We interpret this response to indicate that the AM frequency is too rapid for the force chains to fully form between successive oscillations at these strain rates. This picture is supported by the fact that the viscosity recovery time when the perturbations are turned off is much longer than the AM oscillation period.

We extract the magnitude of acoustic dethickening as a function of strain rates using a phase-sensitive analysis of the instantaneous viscosity response curves (Fig. 4, see Supplemental Material, Sec. IV for details [50]). We observe that the application of the acoustic perturbations decreases the viscosity substantially in the regime where the suspension thickens. This response is sensitive to the strain rate, with the largest decrease occurring in the transition regime [Figs. 4(a) and 4(b)]. We quantify this response by plotting the %Reduction in viscosity vs $\tilde{\dot\gamma}$, the strain rate normalized by the strain rate at the onset of thickening [Fig. 4(c)]. We find a negligible decrease in the viscosity in the Newtonian regime ($\tilde{\dot\gamma} < 1$), in which the force chains are mostly absent. We find the highest reduction in the transition region ($1 < \tilde{\dot\gamma} < 2$), in which the applied acoustic perturbations are sufficient to break up the majority of the force chains. This decrease in viscosity to nearly the Newtonian value effectively shifts the onset strain rate for thickening. Finally, we find that the %Reduction decreases and plateaus in the fully thickened

The format is simple: an abstract summarizes the results. The first paragraph is dedicated to relevant background information, and culminates in the unanswered question that the report will address. The next paragraph will then proceed to explain how the work contained in the report makes progress toward addressing the question. The remainder of the report is dedicated to presenting results. A brief discussion establishes context for the work.

A generic rubrick for grading the final reports:

1. Follows the PRL format (ca. 20 % of total).
   - Title, abstract, authors list using revtex template for PRL. No more than 5 pages for the main report, including figures, etc.
   - 1-2 paragraph introduction for background, going from general to specific.
   - Conclude introductory paragraph with the open question you will address with the report.
   - Next paragraph introduces your method to address the question - `In this letter, we will measure…. We simulate … This paragraph should consist of a concise summary of your results.
   - Specifics of the measurement / simulation approach should be provided, and supported with figures that validate the chosen approach. This portion should be anywhere from 2-5 paragraphs and 1-3 figures.
   - Results should follow – what did you find, and why are you confident in your conclusions? Support with data in figures!
   - Discussion / conclusion – 1-2 paragraphs. Review what you learned, and broaden the discussion to how your measurement / simulation advances the state of the art.
   - References, formatted appropriately.

A generic rubrick for grading the final reports:

2. Figures clear, legible and appropriately captioned (ca. 30 % of the grade)
    - I should be able to understand what you did by reviewing only the figures and captions. They should be clear, legibly labelled, and completely captioned in concise text.
    - All data should be presented with as quantitative a treatement of experimental / simulation error as you can provide.

A generic rubrick for grading the final reports:

3. Writing is clear and concise (ca. 30% of total grade)
    - 5 pages with figures is SHORT! Don’t waste words …
    - Good writing: the process of eliminating *unnecessary words!*
    - Style and clarity count

A generic rubrick for grading the final reports:

4. `Je ne sais quoi' – the effort of the measurement & attempts to reduce noise, and provide excellent, reliable measurements. (ca. 20% of total grade)

- You've learned a lot of methods for reducing noise, and enhancing measurement precision.
- Here is your opportunity to show off – how precise are your measurements? How do they stand in comparison with the state of the art?
- How well have you understood and quantified the various sources of error in the measurement?
- Have you provided sufficient detail in the supplementary document for your report to support your error quantification & technical approach, including details of your simulation?

- You can also score points for identifying paths toward an improved measurement in the discussion – perhaps changing the actuator in some way, or enhancing the load cell's precision, or changing the current range … however you might go about it, if you were given another chance, more time and unlimited equipment, what would you do to improve your measurement?

A summary of the rubrick for grading the final reports:

Item index	Description in brief	Contribution to total grade
1	Follows PRL format (as described above)	20%
2	Figures, data presentation and captioning	30%
3	Writing clarity and style	30%
4	\`Je ne sais quoi' of measurement – excellence / repeatability / quantitative approach – including supplementary material document.	20%

Good vs. Bad captions:

Figure 1. Radish plants showing the effects of freezing at -15C for 2h (A1 and A2) compared with control plants (A4 and B3) kept at room temperature. The plants in pots A1 and A4 were cold acclimated for 2 days at 2.5 C prior to freezing or room temperature treatments. The plants in pots A2 and B3 were not cold acclimated and were kept at room temperature (~ 25C) for 2 days prior to freezing or room temperature treatments. Following the freezing or room temperature treatments, plants were kept in a greenhouse for one week.

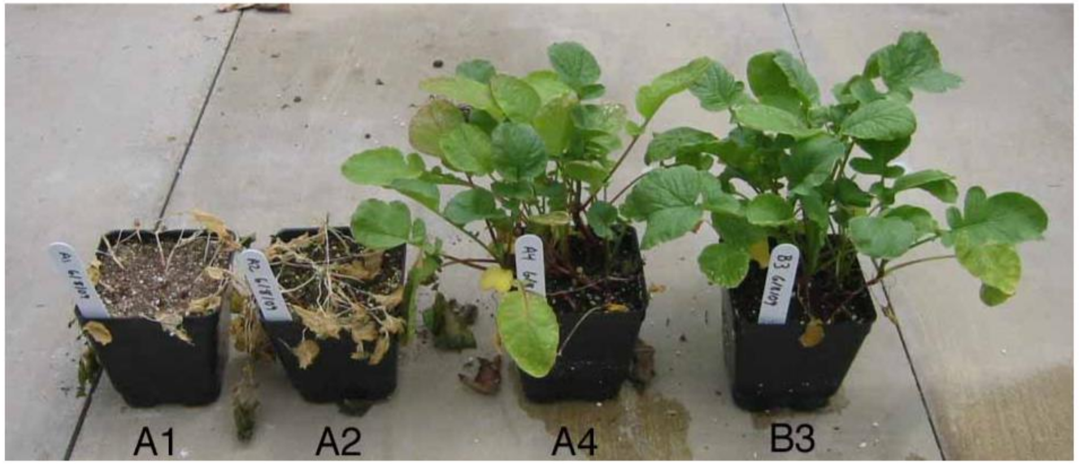
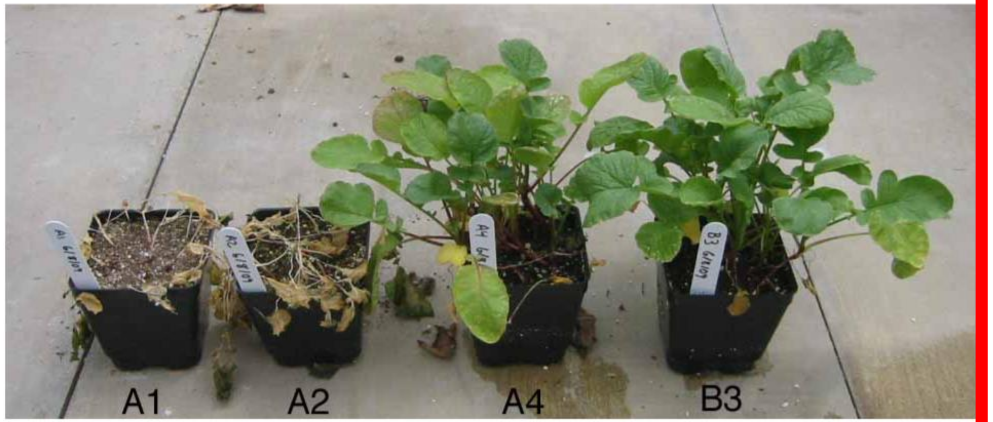


Figure 1. Radish plants subjected to a freezing treatment.



Tentative topical schedule

Date	Anticipated topics
14.9	Introduction to lab hardware / LTspice software; passive circuit components
21.9	Passive filters, Thevenin equivalent circuits; input and output impedence
28.9	Transistors – BJTs and some transistor circuits
5.10	Transistors – Ebers-Moll, differential amplifier and a homemade op-amp
12.10	Op-amps and using positive feedback. The `golden rules'
19.10	Comparators, Schmitt Trigger, Wien Bridge circuit; `Nasty' feedback and how to tame it (sometimes)
26.10	Load cell amplifier circuits, current source circuits that can be used in our measurement
2.11	Build load cell circuit and current source for measurement / model in LTspice; calibrate apparatus
9.11	"
16.11	"
23.11	Carry out in-person testing and write reports
30.11	"
7.12	"
14.12	Present results of measurement to the class (voluntary, extra-credit; via zoom for groups A & C)

Fall semester 2020-2021

- Group A: sciper modulo 3 = 0
- Group B: sciper modulo 3 = 1
- Group C: sciper modulo 3 = 2

date	tu	we
14.09	B	C
21.09	A	B
28.09	C	A
05.10	B	C
12.10	A	B
19.10	C	A
26.10	B	C
02.11	A	B
09.11	C	A
16.11	B	C
23.11	A	B
30.11	C	A
07.12	B	C
14.12	A	B