Couette Shear for Elliptical Particles Near Jamming

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Why Ellipses? Why Couette Shear?

- Ellipses provide “Asymmetry” in particle scale
- Real particles are asymmetric
- Limited experimental studies on asymmetric particles.
- Couette shear enable us to study long term behavior of granular flow, and in particular, diffusion
Experimental Set Up

- Inner wheel velocity: 5 rpm
- Particle aspect ratio: 1.85
- Semi major axis: 0.9 cm
- Time between images: 5 s
Affine and Non-affine failure

\[ r_i' = E \cdot r_i \]  (\( E \) is found from least squares fit)

\[ E = R_\theta \cdot S \]  (\( E \) is decomposed to a symmetric matrix and a rotation)

\[ \epsilon = S - I \]  Strain tensor \( \rightarrow \) Eigenvalues: \( \epsilon_1, \epsilon_2 \)

\[ \delta \epsilon = \epsilon_2 - \epsilon_1 \]  Affine Deformation

\[ 2 \bar{\epsilon} = \epsilon_1 + \epsilon_2 \]  Affine Dilation

\[ D_{min}^2 = \sum (r_i' - E r_i)^2 \]  Characterizes non-affine deformation
Mean Flow

Ellipses

Disks

Note: Mean tangential velocity has similar exponential decay for both disks and ellipses.

Affine Deformation for Ellipses and Disks

Affine deformation is fundamentally similar in ellipses and disks

Affine Dilation for Ellipses and Disks

\[ 2 \bar{\varepsilon} = \varepsilon_1 + \varepsilon_2 \]

Affine dilation in larger \( r \) is still evolving while it has relaxed for smaller radii

Affine dilation is fundamentally similar in ellipses and disks

Departure from local affine deformation (Disks and Ellipses)

\[ D_{\text{min}}^2 = \sum (r'_i - E r_i)^2 \]

Note: Similar behavior was observed for circular disks

\( D_{\text{min}}^2 \) characterizes plastic deformation or departure from affine deformation.

Ellipses

Disks

Affine rotation

\[ \theta' = A \theta \]
Departure from local affine rotation

Define a similar quantity for non-affine rotation:

\[ \theta' = A \theta \]

\[ D_{\min, \theta}^2 = \sum (\theta' - A\theta) \]
Conclusions

- Couette shear is performed on granular system to study dynamical properties of jammed systems.
- Ellipses provide a new orientational field to the problem of jamming.
- Affine and Non-affine changes in ellipses are very similar to disks.

Outlook

- Use force data as dynamical measure
- Study heterogeneity of dynamics by looking at $\chi_4$ measure.