Crossover from collisional to frictional regime in a 3D granular flow

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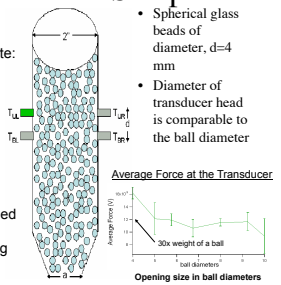
Experimental Setup

- Transducer scan rate: 3.2 x 10^5 Hz
- Normal forces
- Opening size a, varied from 4d to 10d
- Flow velocity ranging from 1.4 cm/s to 30 cm/s



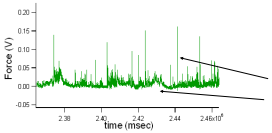
- Spherical glass beads of diameter, d=4 mm
- Diameter of transducer head is comparable to the ball diameter

Average Force at the Transducer

Opening size in ball diameters

Objectives

Typical Force Trace:



Impulse transferred to the wall is both collisional and frictional

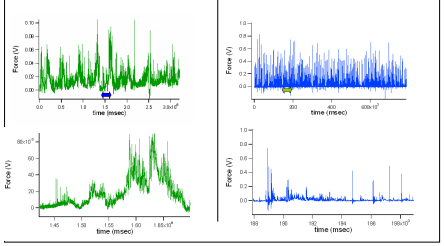
As a function of flow rate:

- Crossover between collisional and frictional mechanisms?
- Distribution of forces?
- Comparison with 2D data[1]

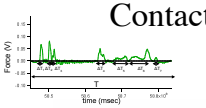
Force traces at different flow rates

Slow flow — 4d, **1.4 cm/s**

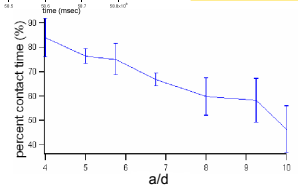
Fast flow — 10d, **30 cm/s**



Contact time



$$\%\ \text{contact time} = \frac{\sum \Delta T_i}{T} \times 100\%$$

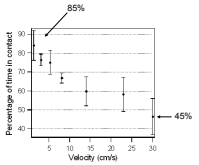


- Frictional forces are significant, even at fast flows
- Almost 100% contact time as approach jamming

Comparison between 2D and 3D

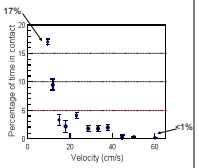
3D

- Frictional forces are a major component controlling the flow, even far from jamming



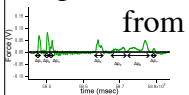
2D

- Collisional forces dominate flow, only see frictional forces as approach jamming

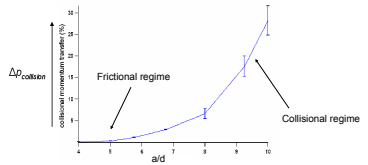


Impulse transferred to the wall from collisions

$t_{collisional}$<60 μsec

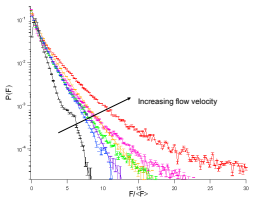


$$\Delta p_{collision} = \frac{\sum \Delta p_{collisional}}{\sum \Delta p_{all}} \times 100\%$$



- Crossover from collisional to frictional forces

Force Histogram

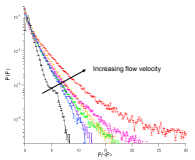


- Non-exponential distribution of large forces
- Shoulder at lowest flow rate?

Comparison to 2D Histograms

3D

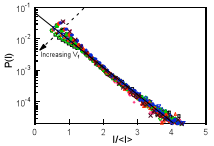
- Force histogram



- Non-exponential distribution of large forces

2D

- Impulse histogram



- **Exponential distribution of impulses**
- **Deviation from exponential at small impulses**

Summary

- A crossover from collisional to almost entirely frictional regime close to jamming in 3D flow
- Frictional forces play a larger role in 3D granular flow than in 2D
- Non-exponential distribution of large forces in 3D histograms

Future Work

- Spatial Correlations from all four transducers

Reference

[1]E. Longhi, N. Easwar and N. Menon, *Phys. Rev. Lett.*, **89** (2002).

Acknowledgments

- Emily Gardel
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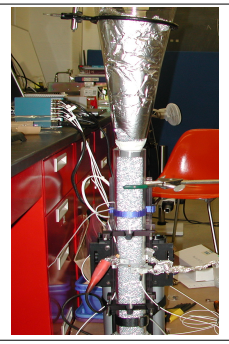

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