



# IFPRI Project Abstract

---

## Controlling Rheology via Boundary Conditions in Dense Granular Flows

Karen E. Daniels

Dept. of Physics, North Carolina State University

Project Start Date: 1 August 2018

Abstract Date: 11 May 2022

---

### ***Project Objective:***

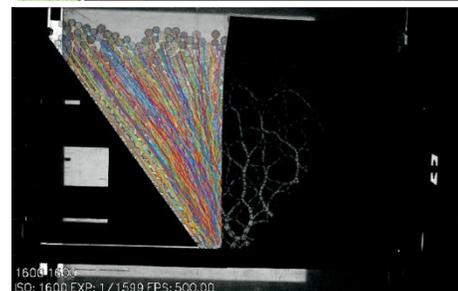
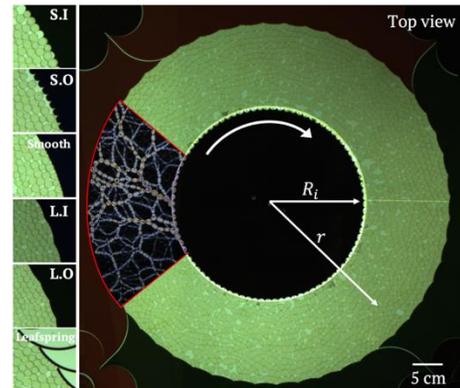
In prior work, we have previously shown that nonlocal rheologies successfully model granular flows across different packing densities, particle sizes and shapes, and shear rates. This success is provided by the measurement and specification of a set of three material properties for a particular set of particles. However, the results of the model depend on *a priori* knowledge of the flow profile, limiting its predictive power. Here we aim to (Q4) understand how changing the roughness and/or compliance of a boundary changes the resulting flow. This will ultimately allow us to determine a set of general principles (Q5) which allow us to correctly set the boundary conditions in nonlinear rheological models, and test their generality in other geometries (Q6).

---

### ***Approach:***

As done during our work for the first funding period, we perform our experiments in an existing quasi-2D annular shear cell with a rotating inner wall and stationary outer wall. Both walls are laser-cut and are interchangeable to modify roughness, as shown at right. In each experiment, we aim to measure both the velocity (shear) profile and the bulk rheology (shear and normal stresses) in order to characterize the dependence of the boundary conditions on both the particle-shape and boundary-characteristics.

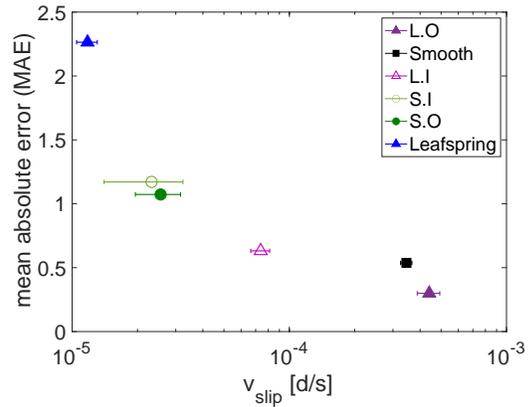
In the past year, we have added a second apparatus that allows us to test the same wall, but in faster flows. This hopper is the same one used by Bob Behringer (IFPRI report FRR 56-06).



---

## ***Recent Results:***

During 2021-2022, graduate student Farnaz Fazelpour has continued conducting experiments and data analysis using a variety of particle and boundary conditions, improving our ability to make quantitative measurements of the stress field, and its spatial and temporal fluctuations. A key finding is that decreased wall slip, which is highly dependent on wall roughness, is associated with an excess of force fluctuations (MAE, in the plot at right).



An undergraduate student, Emily Cecchini, has refurbished a hopper (from Bob Behringer's lab) and made flow measurements using the same boundary shapes as done for the annulus. These runs are at much higher inertial number, and data is collected using a high-speed camera. While the hopper datasets do not provide full stress fields, we are nonetheless observing similar trends as shown above.

---

## ***Next Steps:***

In the remaining few months, we will submit a paper on boundary-condition results from the annular experiment; this work is nearly complete. This summer, we will complete our analysis of the hopper dataset, and present those results in our Final Report. In addition, through a 3-month IFPRI-funded collaboration with Prabhu Nott, we will undertake a comparison between our rheological data and his nonlocal model that accounts for dilatancy under shear.

More broadly, this project has shown that nonlocal models can successfully, quantitatively model granular flows. In order to achieve *predictive* capabilities, a better understanding of how to quantitatively set model parameters and boundary conditions (slip) from either first-principles or simple-experiments still remains.

---