Onset of shear thinning and thickening in frictionless granular system

Wen Zheng(郑文), Yu Shi(时宇), and Ning Xu(徐宁)

Department of Physics, University of Science and Technology of China, Hefei 230026, China

ABSTRACT

We perform non-equilibrium molecular dynamics simulations to analyze the rheology of two-dimensional frictionless granular materials. We find that the steady-flow rheological data show four regimes as a function of increasing shear rate, which can be divided into Newtonian, shear-thinning I, shear thickening, and shear-thinning II, respectively. The magnitude of shear thickening is enhanced as the system size increase and becomes a function located in the infinite system size limit. Before the transition from shear thinning to shear thickening, a strong stress overshoot is observed upon start-up of flow, and its magnitude greatly depends on the shear rate. From the structural point of view, the maximum of the pair distribution function decreases as shear rate increases in shear thickening region, and is sitting at a minimum in the shear thinning region.

INTRODUCTION

Newtonian fluids (like water):

- For most Non-Newtonian fluids, the viscosity decreases with increasing shear rate, that is, they shear thin. Few are reported to do the opposite, that is, shear thicken, despite the longstanding expectation that shear thickening is a generic type of Non-Newtonian behavior.

- Shear thickening is presumed to be due to general mechanisms such as hydrodynamics or dilation.

MODEL OF PACKING OF SPHERES

- N2 big and N2 small frictionless spheres with mass m. Cubic box with periodic boundary conditions ρ_i / n_i = 1.4 → avoid crystallization

- Purely repulsive interactions

STRESS OVERSHOOT ON STARTUP

- start-up of flow curve at different applied shear rate

- Stress normalized by the peak stress

STRESS OVERSHOOT ON STARTUP

- Stress vs. strain, during start-up at for different applied shear rate, for (shear rate increasing with increasing size of overshoot).

- Stress normalized by the peak stress

REFERENCES