A new research on dense liquid suspensions can help make gears for preventing sports injury

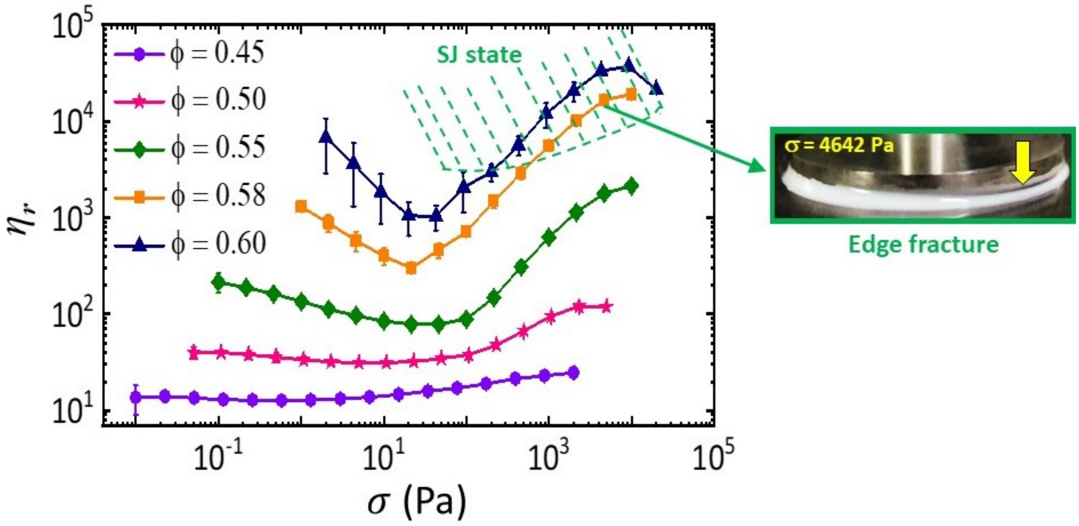
Viscosity of many dense suspensions rapidly increases under an applied stress, a phenomenon which is known as discontinuous shear-thickening or DST. Sometimes, these suspensions can even transform into a solid-like jammed state under very high stress known as shear-jamming (SJ) states. This reversible and almost instantaneous control of suspension viscosity by an external force can have wide range of future applications.

Few recent studies distinguish between DST and SJ states based on transient response measurements or using a secondary probe. Sayantan Majumdar and his students Subhransu Dhar and Sebanti Chottopadhyay of the Soft Condensed Matter group at Raman Research Institute, an autonomous Institute funded by Department of Science and Technology have proposed a novel and direct method for such distinction entirely based on steady-state measurement and without the need of a secondary probe. Sayantan Majumdar is funded through the Ramanujan Fellowship. The research may help designing flexible, impact resistant, protective gears using dense suspensions for injury prevention in sports and security applications.

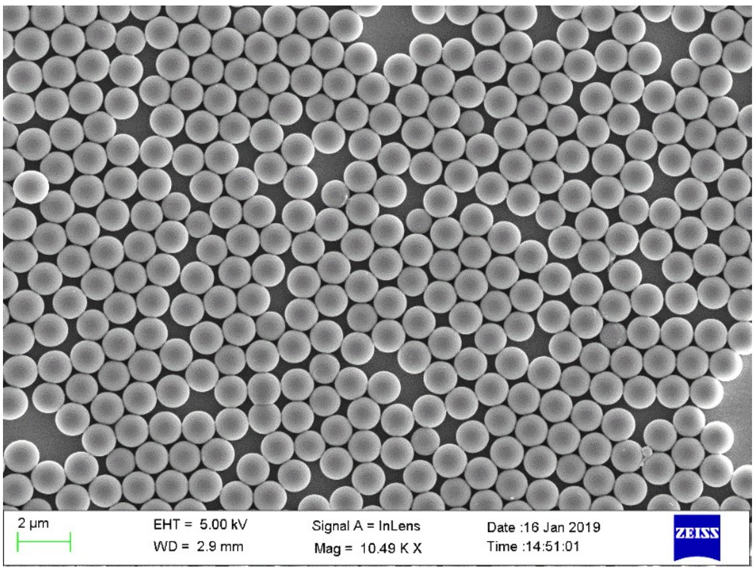
Their method is based on conventional rheology measurements, a branch of physics that deals with the deformation and flow of matter, especially the non-Newtonian flow of liquids and the plastic flow of solids. The paper was published in Journal of Physics: Condensed Matter (J. Phys.: Condens. Matter, 32 (12), 124002, 2019.

“We have found that for small stress values, the viscosity of the suspensions as a function of particle volume fraction can be well described by Krieger-Dougherty (KD) relation. However, for higher values of applied stress (much larger than the stress onset for shear thickening), KD relation systematically overestimates the measured viscosity, particularly for higher volume fractions,” said the scientists. This systematic deviation can be rationalized by the weakening of the sample due to flow induced fractures and failures when the sample is in a solid like SJ state. Using Wyart-Cates model, a model which gives fraction of particles making frictional contacts for a given applied stress value, they have proposed a method to predict the SJ onset from the steady state rheology measurements. Their results are further supported by in-situ optical imaging of the sample boundary under shear.

The idea for this new method was triggered by observing crack formations at the sample boundary under shear triggered the idea. They synthesized polystyrene microspheres (PS) in large scale in their Soft and Adaptive Materials lab at RRI using a technique called dispersion polymerization. The particle size is characterized by scanning electron microscopy (SEM). Suspensions are formed by dispersing PS particles in polyethyleneglycol (PEG-400) at different volume fractionsranging from 0.4 to 0.6. Rheology measurementsare carried out in the lab using a stress controlled Rheometer (MCR-702, Anton Paar, Austria) with parallel plate (plate diameter of25 mm and a gap of 300 μm) and cone and plate (cone diameterof 25 mm and cone angle 2°) geometries at a temperatureof 25 °C.



10^5
10^4
10^3
10^2
10^1
η_r
$\phi = 0.45$
$\phi = 0.50$
$\phi = 0.55$
$\phi = 0.58$
$\phi = 0.60$
SJ state
10^{-1}
10^1
10^3
10^5
σ (Pa)
σ = 4642 Pa
Edge fracture



2 µm
EHT = 5.00 kV
WD = 2.9 mm
Signal A = InLens
Mag = 10.49 K X
Date :16 Jan 2019
Time :14:51:01