We apply our simulation routine with following features:

- Yukawa type interaction pair-potential with: 
  \[ U(r) = -\frac{e^{-r/a}}{r} \]
  where \( a = \sqrt{\frac{\sigma}{\kappa}} \) (a is the lattice constant, \( \sigma = 1.2 \) is the Yukawa screening parameter)

- cut-off distance in force calculation ensures \( e^{-10} \) relative force error

- large system size with a particle number \( N = 11400 \)

- rectangular simulation box to match hexagonal ground state lattice

- wide range of shear rates: \( \dot{\gamma} \in [0.004, 4.00] \)

- perturbation frequencies: \( \omega \in [0.01, 1.5] \)

- where \( \omega = \sqrt{2k_B T / m} \) (m a)

- Ewald's coupling parameter:
  \[ E_{\text{cut}} = 100,000/\Omega \]

I. Gaussian thermostated SLLOD equations of motion in planar Couette flow:

\[ \frac{d\mathbf{r}_i}{dt} = \mathbf{v}_i, \quad \frac{d\mathbf{v}_i}{dt} = -\nabla U(r) - \frac{1}{m} \mathbf{F}_i + \mathbf{F}_\text{ext} \]

where \( \mathbf{r}_i, \mathbf{v}_i \) are the position and velocity of the particle \( i \), \( \mathbf{F}_i \) is the total force on the particle, \( \mathbf{F}_\text{ext} \) is the external force, and \( \mathbf{F}_\text{ext} = -\nabla U(r) \) is the Lennard-Jones potential.

II. Langevin simulations equations of motion:

\[ \frac{d\mathbf{r}_i}{dt} = \mathbf{v}_i, \quad \frac{d\mathbf{v}_i}{dt} = -\nabla U(r) - \frac{1}{m} \mathbf{F}_i + \mathbf{F}_\text{ext} + \frac{1}{m} \zeta_i \]

The following quantities are calculated, after 200 cycles of waiting the system to reach steady oscillation, during the 400 measurements cycles:

- Complex viscosity: \( \eta = \eta'' + \eta' \)

- First peak of pair correlation function:

Summary:

In the small shear limit our 2D simulation results are in good qualitative agreement with 3D simulation results [2]. We obtain good agreement with 3D dusty plasma experiments [3] for the shear rate dependence of the viscosity at small excitation frequencies and [4] frequency dependence of the viscosity at intermediate shear rates. At high shear rates and frequencies our results agree with those of the 3D dusty plasma experiments, and the monotonous behavior of shear viscosity. Comparing SLLOD with the shear Langevin simulations shows that the global thermostat of the former fails at low excitation frequencies. Our simulations show a peak in the absorbed energy near the Einstein frequency at intermediate shear rates \( \dot{\gamma}_c \). An essential component of the characteristically damped oscillation is near the plasma frequency of the longitudinal wave dispersion. Significant configurational anharmonicity develops at small frequencies and high shear rates resulting in the change of structural properties.

References: