Spatial force correlations in granular shear flow.

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One of the most challenging areas in research on granular media is understanding the jamming transition. Much, although not all, of the recent work has focused on quenched systems above the jamming density[1]. Above the jamming density, force chains percolate from boundary to boundary[2], providing a rigid structure, and hence a yield strength. In the paper above, and its immediate sequel, Lois et al. consider dynamical shear for solids fractions, ν, which are below the jamming value. They have chosen to numerically model systems of particles, using the contact dynamics approach, pioneered by Moreau[3]. Systems of rigid particles with dissipative interactions are subject to uniform shear. The shear is necessary, of course, since otherwise the particles would come to rest in a non-rigid state. By using rigid particles and by staying below the critical $\nu = \nu_c$ for jamming, the flows are always in the inertial or Bagnold region where the dynamics are exclusively controlled by the shear rate.

The question that Lois et al. seek to answer is simple: what is the signature of jamming as ν is increased from below towards the jamming transition? To address this question, they consider a force correlation function, $C(\ell)$ based on the net force on each particle. Perhaps the most important observations from this research are 1) that the $C(\ell)$ decays exponentially at long ℓ, thus defining a correlation length, ξ, and 2) that this correlation length appears to diverge as ν approaches the jamming value. As one might expect, C depends on the orientation; it is greatest along the compressive direction of the shear flow. It is perhaps worth noting that a typical uniform shear involves compression in one direction and corresponding dilation in the transverse direction. Thus, forces are most strongly transmitted along the compressive direction, and most weakly transmitted along the dilational direction.

By considering the distributions of inter-particle forces, $P(f)$, Lois et al. argue that there is a transition from a dilute regime where binary collisions dominate to a denser regime, still below ν_c, where clusters of particles become important. They find that the binary-cluster transition occurs when the correlation length ξ satisfies $\xi/\xi_{el} = 1.25$, where ξ_{el} is the dilute limit of ξ, determined strictly by binary collisions. Thus, the measured distributions, $P(f)$, and those that would be expected based on purely binary collisions differ measurably for $\xi/\xi_{el} > 1.25$. In particular, $P(f)$ shows a peak for low f in the binary collision regime, but that peak dissappears in the clustering regime. Interestingly, the binary/clustering transition depends on how dissipative the inter-particle interactions are. The more elastic the interactions, the closer to ν_c binary collisions dominate.

This work shows that on approaching ν_c, the usual assumption of binary collisions breaks down. Lois et al. pursue this issue in the follow-up paper, Phys. Rev. E **76**, 021303 (2007). In addition, this work takes a step closer to having a more unified description of the jamming transition, in this case by addressing the regime of densities $\nu < \nu_c$. The apparent divergence of ξ observed by Lois et al. is also interesting since Majmudar and Behringer[2] report that for sheared systems above ν_c there may be long-range force correlations as well. In this case, the system is static, and hence a different force correlation function is needed that reflects the magnitude of the average force on a particle. There is also some interesting experimental evidence indicating that $P(f)$ does reflect the nearness to jamming in typical shear flows. For instance, Howell and al.[4] and Corwin et al.[5] report $P(f)$'s for shear flows near jamming that have a maximum at $f = 0$.

References

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