Stresses and orientational order in shearing flows of granular liquid crystals

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We perform discrete element simulations of homogenous shearing of frictionless cylinders and show that the particles are characterized by orientational order and form a granular liquid crystal. For elongated and flat cylinders, the alignment is in the plane of shearing, while cylinders having aspect ratio equal to 1 and 0.8 show no orientational order. We show that the particle pressure is insensitive to the cylinder aspect ratio and well predicted by kinetic theory of granular gases, with a singularity in the radial distribution function at contact different from that for frictionless spheres. The numerical results quantitatively agree with physical experiments on different geometries. The particle shear stress is affected by orientational anisotropy. We postulate that, for frictionless cylinders, the viscosity is roughly due to the motion of the orientationally disordered fraction of the particles, and show that it is proportional, through the order parameter, to the expression of kinetic theory. Finally, we suggest that the orientational order is the result of the competing effects of the shear rate, which induces alignment, and the granular temperature, which ramdomizes.