Granular fluids driven by a scochastic bath with friction

M. G. Chamorro, F. Vega Reyes and V. Garzó
Departamento de Física, Universidad de Extremadura, E-06071 Badajoz, Spain

Granular systems are constituted by macroscopic grains that collide inelastically so that the total energy of the system decreases with time. Thus, in order to maintain the granular medium in a fluidized state, an external energy input is needed to compensate for the collisional loss of energy and achieve a *steady* nonequilibrium state. In most of the experiments, energy is supplied through the boundaries causing spatial gradients in the system. To avoid the difficulties associated with inhomogeneous states, it is usual in computer simulations to heat the system by the action of an external driving force (thermostat). Nevertheless, in spite of its practical importance, little is known about the influence of the thermostat on the properties of the system[1].

The goal of this contribution is to analyze the homogeneous steady state of a driven granular fluid described by the Enskog-Boltzmann kinetic equation. In order to reach a steady state, the particles are assumed to be under the action of an external thermostat composed by two different forces: (i) a stochastic force where the particles are randomly kicked between collisions[2] and (ii) a viscous drag force which mimics the interaction of the particles with an effective viscous "bath". One of the main advantages of using this kind of thermostat[3] with respect to others present in the literature[2] is that the temperature of the thermostat T_b (different from the temperature $T < T_b$ of the granular fluid) is always well defined. In particular, for elastic collisions, the fluid equilibrates to the bath temperature ($T = T_b$). Moreover, some recent results[4] suggest that this thermostat is the most appropriate to modelize some experiments.

Our study follows two complementary routes: (i) an analytical solution obtained from a Sonine polynomial expansion and (ii) a numerical solution of the Enskog-Boltzmann equation obtained by means of the direct simulation Monte Carlo (DSMC) method. Our results are also compared with recent molecular dynamics (MD) simulations performed by other authors[3]. Comparison at the level of the (steady) granular temperature T_s and the fourth cumulant of the velocity distribution function shows in general a good agreement, even for strong values of dissipation. As an illustration, the (steady) temperature T_s is plotted in Figure 1 as a function of the solid volume fraction ϕ. It is quite apparent that the agreement between theory with MD simulations data from[3] is very good. In addition, as expected, at a given value of density, the granular temperature decreases as the gas becomes more inelastic.

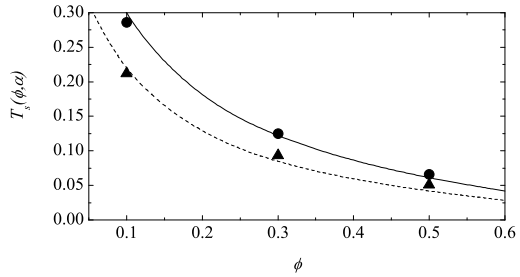

FIG. 1. Plot of the (steady) granular temperature T_s (measured in units of the bath temperature T_b) versus the volume fraction ϕ for a two-dimensional system and two different values of the coefficient of restitution: $\alpha = 0.8$ (solid line) and $\alpha = 0.6$ (dashed line). The symbols are the simulation data (circles for $\alpha = 0.8$ and triangles for $\alpha = 0.6$) obtained by Gradenigo *et al.*[3].

ACKNOWLEDGEMENTS

This work has been supported by the Spanish Government through Grants No. FIS2010-16587 and (only F. V. R.) No. MAT2009-14351-C02-02, partially financed by FEDER funds and by the Junta de Extremadura (Spain) through Grant No. GR10158.

[1] V. Garzó and A. Santos, *Kinetic Theory of Gases in Shear Flows. Nonlinear Transport* (Kluwer Academic, Dordrecht, 2003).

[2] D. R. M. Williams and F. C. MacKintosh, *Phys. Rev. E* **54**, R9–R12 (1996).

[3] G. Gradenigo, A. Sarracino, D. Villamaina, and A. Puglisi, *J. Stat. Mech.* P08017 (2011).

[4] G. Gradenigo, A. Sarracino, D. Villamaina, and A. Puglisi, *Europhys. Lett.* **96**, 14004 (2011)