Thermal convection in granular gas of hard disk with dissipative lateral walls under zero gravity

Álvaro Rodríguez-Rivas[1], Miguel Ángel López-Castaño[1], and Francisco Vega Reyes[1,2]
[1]Departamento de Física, Universidad de Extremadura, av. Elvas s/n, 06071 Badajoz, Spain
[2]Instituto de Computación Avanzada (ICCAEx), Universidad de Extremadura, av. Investigación s/n, 06071 Badajoz, Spain

We study in this work the properties of thermal convection in a granular system with no gravity (i.e., $g = 0$). As it is known, Rayleigh-Bénard convection results from the competition of a thermal gradient against gravity volume [1]. Usually, this thermal gradient is caused by temperature sources. In the present work, however we specifically analyze the role of thermal gradients caused by the action of dissipative walls. More specifically, we study thermal convection in a low density granular gas enclosed by four walls when there is no gravity. Some previous studies suggest that dissipative walls (DW, lateral in the sense that they are perpendicular to gravity, if present) are the direct cause of the automatic appearance of convection cells, in a granular under the action of a gravity field [2].

In this work, we show that *this dissipative-wall-driven convection is present also when there is no gravity*. For this, we present event-driven MD simulations of granular gas composed of identical smooth hard disks. As we said, the system is enclosed by four walls, and there no gravitational field (i.e., $g = 0$). In Fig. 1 we can see the shape of the convection generated in this kind of configuration. The walls delimit a rectangular region and the rotational degrees of freedom of particles are ignored (our discs are spinless). The kinetic energy loss upon a particles pair is characterized by a constant coefficient of normal restitution, denoted as α. The system is also provided a pair of walls (in Fig 1, the horizontal walls) with a kinetic energy source. We denote the other two walls as "lateral" walls. The lateral walls-particle collisions are characterized by a constant coefficient of normal restitution denoted as α_{w}.

When the lateral walls are elastic (wall-particle collisions preserve kinetic energy), the system shows a steady base state that is hydrostatic, but if the α_{w} parameter decreases, i.e., the lateral walls act as a surface energy sink, the steady state becomes convective [3]. Dissipation at the lateral walls generates an additional gradient that is perpendicular to thermal gradient from temperature sources.

In order to clarify the role of the walls in the generation of the new convection steady state, it is necessary to characterize completely the transition from hydrostatic state to convective state, for different system parameters values. We present a complete analysis of the behavior of the DW convection with $g = 0$. We have studied the effect of the parameter α_{w} for different temperatures of the horizontal walls and constant coefficient of normal restitution α to characterize the transition to the steady convection convective at zero gravity.

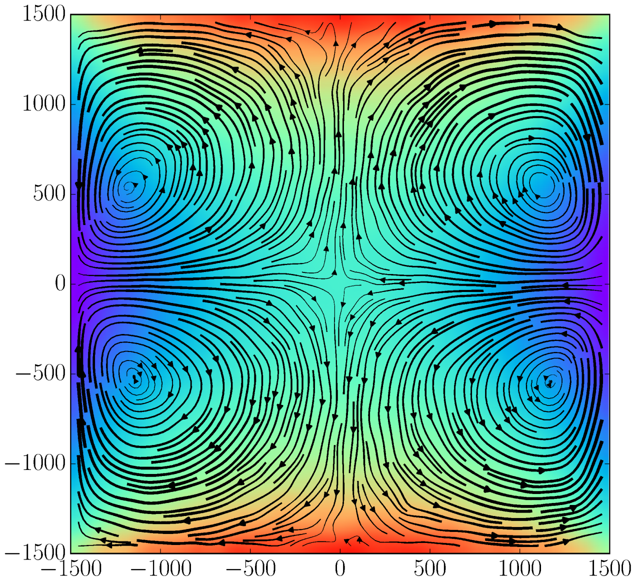

Fig. 1. Convection lines for the velocity field superimposed on the temperature field, evaluated on 2500 MFT of the granular gas with $\rho = 0.0016$. Thickest stream lines correspond to higher values of the velocity field $3 \times \sqrt{u_x^2 + u_y^2}/v_{\max}$ (in our dimensionless units). The relevant parameters are: $T = 1$ for horizontal walls, $\alpha_{\mathrm{w}} = 0.4$ for laterals, and $\alpha = 0.9$.

[1] F. H. Busse, Rep. Prog. Phys. **41**, 1929-1967 (1978).

[2] G. Pontuale, A. Gnoli, F. V. Reyes, and A. Puglisi, Phys. Rev. Lett. **117**, 098006 (2016).

[3] F. V. Reyes and A. R. Rivas, (unpublished).

[4] F. V. Reyes and J. S. Urbach, J. Fluid Mech. **636**, 279-283 (2009).