Thermal memory in a vibrated thin granular layer

Álvaro Rodríguez-Rivas[1],
Francisco Vega Reyes[2,3] and Miguel Ángel López-Castaño[2]
[1]Department of Physical, Chemical and Natural Systems, Pablo de Olavide University, 41013, Sevilla, Spain
[2]Departamento de Física, Universidad de Extremadura, 06071, Badajoz, Spain
[3] Instituto de Computación Científica Avanzada (ICCAEx), Universidad de Extremadura, 06071, Badajoz, Spain

In this experimental/computational study, we present the first evidence of existence of Kovacs and Mpemba effects in vibrated granular layer. Recently, it has been theoretically shown that these effects should occur, under the appropriate initial conditions, in a homogeneous granular gas [1, 2]. The Mpemba effect occurs when the system displays an anomalous cooling/heating rate, as a consequence of which, a warmer system may cool down faster, for instance. Kovacs effect consists in an anomalously non-monotonic relaxation of a macroscpic variable (granular temperature, in our case).

Under experimental conditions, however, complete homogeneity is not strictly attainable in a driven granular system (for instance, the system is not homogeneous in the vertical, in the case of a vertically vibrated layer [3], and for this and other reasons, it remained to be confirmed the existence of these effects in a realistic configuration that could be reproduced in the laboratory.

For this purpose, we have performed molecular dynamics simulations (MD) of a vertically vibrated layer, and have set-up an experiment in the laboratory. Both experiments and simulations had to be conducted however under higher density conditions, since, as we will show, the gas phase does not actually exist in this particular configuration, due to geometric restrictions and the particular features of the dynamics of inelastic particles.

The Kovacs effect is, in particular, very noticeable, as Figure 1 shows. In the presentation, we will explain in more detail the specific features of the observed memory effects and the restrictions for these to appear in our experimental configuration.

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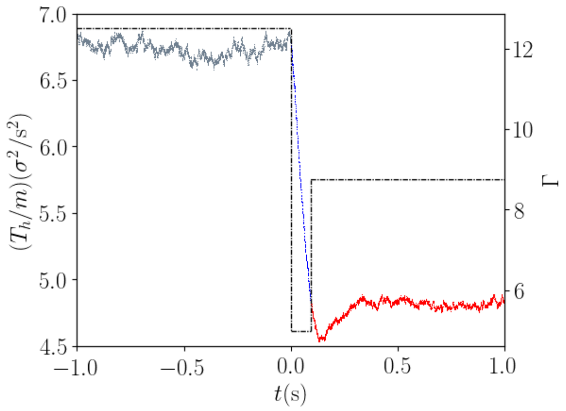

Fig. 1. Kovacs effect in a dense granular layer. σ stands for particle diameter, T_h is the XY average kinetic energy, m for particle mass Γ is the shaking acceleration (as defined in [3], in units of $g = 9.8\ \mathrm{m/s^2}$). The thermal protocol is indicated with dashed lines (the energy input). The granular temperature T_h is indicated with continuous lines, with different coloring for the different thermal protocol stages. Anomalous non-monotonic evolution of T_h occurs in the final relaxation stage (red curve), which is signaled, as it can be seen, with the presence of an absolute minimum.

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