Granular gas mixtures of inelastic rough particles: Hard disks and hard spheres

Alberto Megías[1] and Andrés Santos[1,2]
[1]Departamento de Física, Universidad de Extremadura, 06006 Badajoz, Spain
[2]Instituto de Computación Científica Avanzada (ICCAEx), Universidad de Extremadura, 06006 Badajoz, Spain

Granular gas mixtures modeled as systems of inelastic and rough particles, either hard disks on a plane or hard spheres, are considered. Both classes of systems are embedded in a three-dimensional space ($d = 3$) but, while in the hard-sphere (HS) case the translational and angular velocities are vectors with the same dimensionality $d_\mathrm{t} = d_\mathrm{r} = 3$, in the hard-disk (HD) case the translational velocity vectors are planar (i.e., $d_\mathrm{t} = 2$) and the angular velocity vectors are orthogonal to the motion plane (i.e., $d_\mathrm{r} = 1$). This complicates a unified presentation of both classes of systems, in contrast to what happens for smooth, spinless particles, where an unambiguous kinetic-theory treatment of d-dimensional spheres is possible [1].

The kinetic-theory derivation of the energy collisional production rates ξ_{ij}^{tr} and ξ_{ij}^{rot} (where the indices i and j label different components) has been separately carried out for HS [2] and HD [3] multicomponent granular gases. The major aim of this work is to unify those studies by expressing ξ_{ij}^{tr} and ξ_{ij}^{rot} in terms of the dimensionality d_t, after setting $d_\mathrm{r} = 2d_\mathrm{t} - 3$. The HS and HD expressions are recovered by particularizing to $d_\mathrm{t} = 3$ and $d_\mathrm{t} = 2$, respectively. Moreover, in the case of spinless particles with $d = d_\mathrm{t}$, known energy production rates $\xi_{ij}^{\mathrm{tr}} = \xi_{ij}$ of smooth d-dimensional spheres [1] are recovered.

Our results are applied to a comparative analysis of the homogeneous free cooling of HD and HS gases. As an illustration, Fig. 1 shows a density plot of the rotational/translational temperature ratio as a function of the coefficients of normal (α) and tangential (β) restitution. As can be observed, the disparity between both types of temperature is generally more pronounced in the case of disks than in the case of spheres. A similar behavior is exhibited by the rotational/translational nonequipartition in binary mixtures; however, the component/component degree of nonequipartition is stronger in HS gases than in HD gases.

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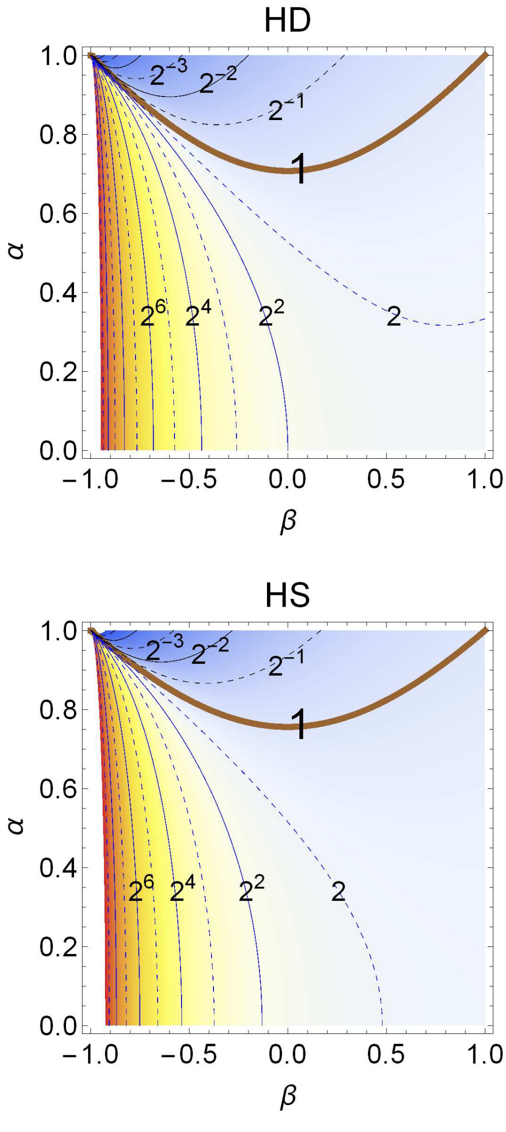

Fig. 1. Density plot of the rotational/translational temperature ratio for HD (top) and HS (bottom) granular gases. The contour lines correspond to the values 1 (thick solid lines), $(2^{-1}, 2^{-2}, \ldots)$, and $(2, 2^2, \ldots)$