Thermal diffusion segregation in granular mixtures

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Among the different competing mechanisms involved in granular segregation, thermal diffusion becomes the most relevant one when an external energy input drives the system into rapid flow conditions. In this regime, granular matter flows like a fluid and kinetic theory tools (conveniently adapted to account for the inelastic character of collisions between grains) can be quite useful to analyze thermal diffusion segregation. Thermal diffusion is caused by the relative motion of the components of a mixture due to the presence of both gravity and a temperature gradient. Due to this motion, a steady state is reached where the separation effect arising from thermal diffusion is balanced by the remixing effect of ordinary diffusion. The aim of this contribution is determine the so-called thermal diffusion factor Λ of a moderately dense granular binary mixture (with coefficients of normal restitution α_{ij} for collisions between particles of species i with j) described by the (inelastic) Enskog kinetic equation. A segregation criterion is derived from the knowledge of Λ, which is explicitly obtained in terms of the parameters of the system (masses and sizes of particles, concentration, solid volume fraction and coefficients of normal restitution) [1]. The sign of Λ determines the tendency of the large particles to drift toward the cooler or warmer plate. To test the reliability of the theoretical calculations, the factor Λ is also obtained by computer simulations [Monte Carlo (DSMC) and molecular dynamics (MD) simulations] carried out for a granular impurity (species 1) in a driven low-density granular gas [2]. As an illustration, Fig. 1 shows the marginal segregation curve ($\Lambda = 0$) for a system with $\alpha_{22} = 0.9$ and $\alpha_{12} = 0.7$. It is quite apparent that theory reproduces very well the phase diagram obtained from simulations.

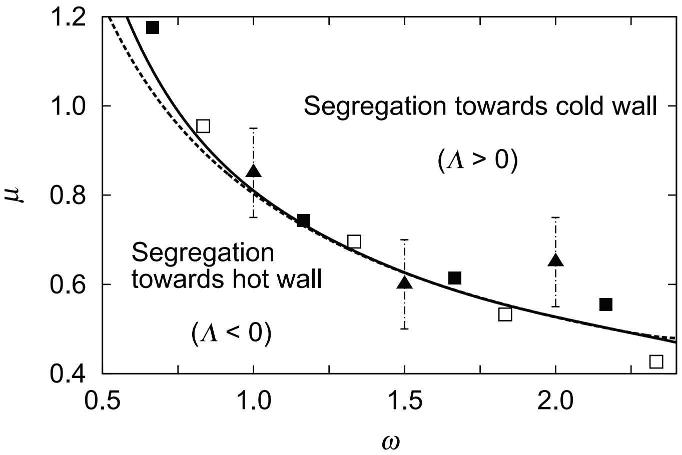

FIG. 1: Phase diagram in the $\{\omega, \mu\}$-plane, where $\omega \equiv \sigma_1/\sigma_2$ and $\mu \equiv m_1/m_2$. Here, σ_i and m_i denote the diameter and mass of particles of species i, respectively. Dashed and solid lines represent theoretical predictions derived for two different driven states (stochastic external force and/or sheared gas). Symbols refer to computer simulation results (triangles, MD; squares, DSMC).

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[1] Garzó, V. *Phys. Rev. E*, **78**, pp. 020301 (R), 2008; *Eur. Phys. J. E*, **29**, pp. 261-274, 2009; *New J. Phys.*, **13**, pp. 055020, 2011.
[2] Vega Reyes, F., Garzó, V. and Khalil, N., *Phys. Rev. E*, **89**, pp. 055206, 2014.