Polydisperse hard rectangles: A simple model for vibrated monolayers of granular rods.

Ariel Díaz-De Armas[1] and Yuri Martínez-Ratón[1]
[1]Universidad Carlos III de Madrid, Departamento de Matemáticas.
Avenida de la Universidad 30, 28911, Leganés, Madrid.

We study the effect of length-polydispersity on the phase behavior of freely-rotating hard rectangular particles. Recent experiments on monolayers of quasi-two-dimensional granular rods vibrated in the vertical direction showed the presence of different liquid-crystal textures like isotropic (I), nematic (N), tetratic (T), and smectic (S) phases. Granular particles often exhibit large degree of polydispersity in length, so it is important to quantify its effect on the phase behavior. As a first approximation we used a hard-particle mean-field model based on the free-energy density functional. We have taken particles with rectangular shape because many experiments usually employ monolayers of metallic cylinders which have rectangular projected areas.

The rectangles can freely rotate in 2D and are polydisperse in length while their thickness is kept constant. We have taken a Schultz length-distribution function and also a distribution with a Gaussian tail to model the polydispersity and calculated the phase diagrams (density vs. particle aspect ratio) for different degrees of polydispersity (quantified through, Δ_0, the mean square deviation of the density distributions). The phase diagrams for the one-component and polydisperse (with polydispersity $\Delta_0 = 0.408$) hard rectangles are shown in the figure. We found that the T phase stability decreases with polydispersity while the I-N phase transition becomes strongly of first order. The I-N tricritical point, already present in the one-component system, moves to higher aspect ratios. Our calculations suggest the existence of a terminal polydispersity above which the I-N transition becomes always of first order. We found strong, driven by polydispersity, particle fractionation between the coexisting I and N phases. We also studied in detail the orientational ordering of particles in both, N and T phases, as a function of polydispersity. Our results might help to understand the phase behavior of granular monolayers of rods in recent experiments conducted by our group.

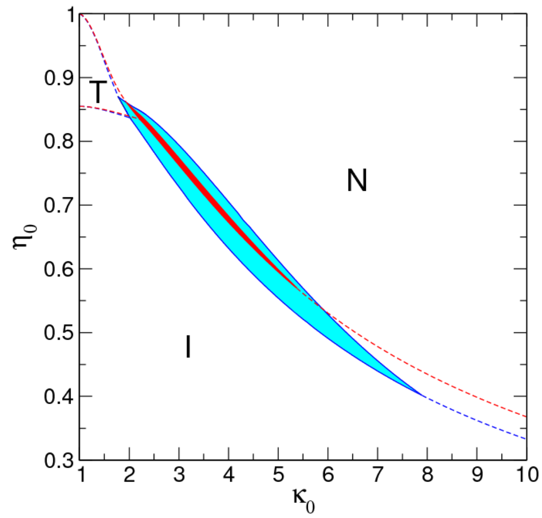

Figure 1: Phase diagrams in the volume fraction (η_0)-mean aspect ratio (κ_0) plane of monodisperse (shown in red) and polydisperse (shown in blue/cyan) hard rectangles. The polydisperse length-distribution function is selected to be of Schultz type and the polydispersity is $\Delta_0 = 0.408$. The regions of stability of I, N, and T phases are labelled and the coexistence regions are shaded.