Of traffic jams, beach sands and the zero-temperature jamming transition

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Researchers in condensed matter physics at the University of Pennsylvania and the University of Chicago have created an experimental and computer model to study how jamming, the physical process in which collections of particles are crammed together to behave as solids, might affect the behavior of systems in which thermal motion is important, such as molecules in a glass.

The study presents the first experimental evidence of a vestige of the zero temperature jamming transition — the density at which large, loose objects such as gas bubbles in liquid, grains of sand or cars become rigid solids such as foam, sand dunes or traffic jams — in a system of small particles where thermal energy is important. This demonstrates that despite the fact that the size of constituent particles differ by many orders of magnitude, molecules in a glass retain an echo of the phenomenon of how boulders coming to rest to form a solid rock pile.

"We have been testing the speculation that jamming has a common origin in these different systems," Andrea Liu, an author of the study and professor in the Department of Physics at Penn, said.

The paper appears in the current issue of the journal *Nature*.

The idea of jamming is that slow relaxations in many different systems, ranging from glass-forming liquids to suspensions of particles such as bits of ice in a milkshake to foams and granular materials, can be viewed in a common framework. For example, one can define jamming to occur when a system develops a yield stress or extremely long stress relaxation time in a disordered state. Foams and granular materials flow when a large shear stress is applied but jam when the shear stress is lowered below the yield stress. But systems of large particles such as foams and granular materials can be considered zero-temperature systems because the energy associated with a typical temperature, such as room temperature, is negligible compared to the energy required to shift the particles. As a result, it is not known whether the jamming of such systems is related to the jamming of systems of small particles, such as molecular liquids, which jam as temperature is lowered through the glass transition.

The Penn study involved mathematical computer simulations and an experiment to touch on this very general problem. The analysis focuses on an intuitive feature of the system, the separation between neighboring spheres, and, in particular, on how this separation evolves as the system becomes jammed. By confining soft microspheres that swell and shrink by changing the temperature of the system and that are small enough so that thermal motion is important, researchers were able to study how the separation distance evolves as the volume occupied by the spheres is varied through the jamming transition. The experiments discovered a vestige, at non-zero temperature, of one of the important structural signatures to arise at the zero-temperature jamming transition.

The computer simulations and experiments provide new clues about the connections between jamming and the glass transition and provide a concrete experimental route to explore them.

"Most people have experienced jamming and unjamming in one way or another, by sitting in a traffic jam or tapping a container of flour to get the powder to flow," said. "But we also use jamming to make the strongest metallic alloys and toughest plastics. Elucidation of the principles of jamming, therefore, holds potential to be of practical importance and will most certainly be of interest to anyone who has wondered why honey ceases to flow when it is cooled in a refrigerator or why earth or snow can suddenly form avalanches with catastrophic results."

Source: University of Pennsylvania (news : web)

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