

Levitation trick gives drag the slip

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Plunging hot spheres into viscous liquids reveals a way to reduce fluid resistance without complex engineering procedures.

The erratic scooting of water droplets around sizzling frying pans occurs when layers of trapped vapor cause the drops to briefly float. A team from King Abdullah University of Science and Technology (KAUST), Saudi Arabia, has shown that this process, known as the Leidenfrost effect, can be used to significantly cut the drag forces faced by objects traveling through liquids.

A baseball's special stitches and the dimples on golf balls are not just cosmetic. At sufficient speeds, these rough textures cause a thin boundary layer of air flowing over the sphere to behave turbulently and reduce the friction to a level below that of smooth surfaces. This so-called drag crisis lets these balls achieve longer and more stable trajectories.

Recently, Siggi Thoroddsen, Professor of Mechanical Engineering, and Ivan Vakarelski from KAUST investigated techniques to trigger drag without invoking the crisis phenomenon. They achieved this by reversing usual Leidenfrost procedures and immersing hot spheres into liquids. With sufficient evaporation, a vapor layer formed that acted as lubricant to reduce liquid-solid friction. This approach enabled hot spheres to move twice as fast as cooler orbs during free-fall experiments.

However, both the drag crisis and Leidenfrost-induced levitation take place under a narrow range of a parameter, known as the Reynolds

number, which relates fluid viscosity and density to the size and speed of a traveling sphere. In their latest work, Vakarelski, Thoroddsen and collaborators in Australia used liquids with unique stabilizing properties to dramatically expand the conditions under which Leidenfrost vapor layers diminish drag forces.

The researchers dropped the scalding spheres into tall vertical tanks containing perfluorocarbons, liquids often used as refrigerants that evaporate more easily than water. High-speed video cameras captured the free-fall trajectories of spheres in perfluorocarbons with widely different viscosities to explore a range of drag conditions. Surprisingly, the vapor layer reduced friction by much more than was expected, and did so successfully for Reynolds numbers spanning three orders of magnitude.

Modeling of this process revealed that the Leidenfrost effect induced the liquid flowing around the sphere to slip and take on different velocities. Thoroddsen explained that, "As we slowly introduce more slip, this progressively reduces the drag. The partial slip is determined by the relative viscosity of the liquid and the gas molecules in the vapor layer."

The team anticipates that vapor layers naturally sustained on superhydrophobic surfaces, or induced via bubble injection, may stimulate development of unexpected friction-cutting techniques. "These experiments just give an upper bound for [drag](#) reduction—once engineers see the possibilities, the potential payoff could be large," added Thoroddsen.

More information: Ivan U. Vakarelski et al. Leidenfrost Vapor Layers Reduce Drag without the Crisis in High Viscosity Liquids, *Physical Review Letters* (2016). [DOI: 10.1103/PhysRevLett.117.114503](https://doi.org/10.1103/PhysRevLett.117.114503)

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