

# Predicting Leidenfrost-Induced Droplet Motion On A Herringbone-Ratchet Using COMSOL Multiphysics® And MATLAB®

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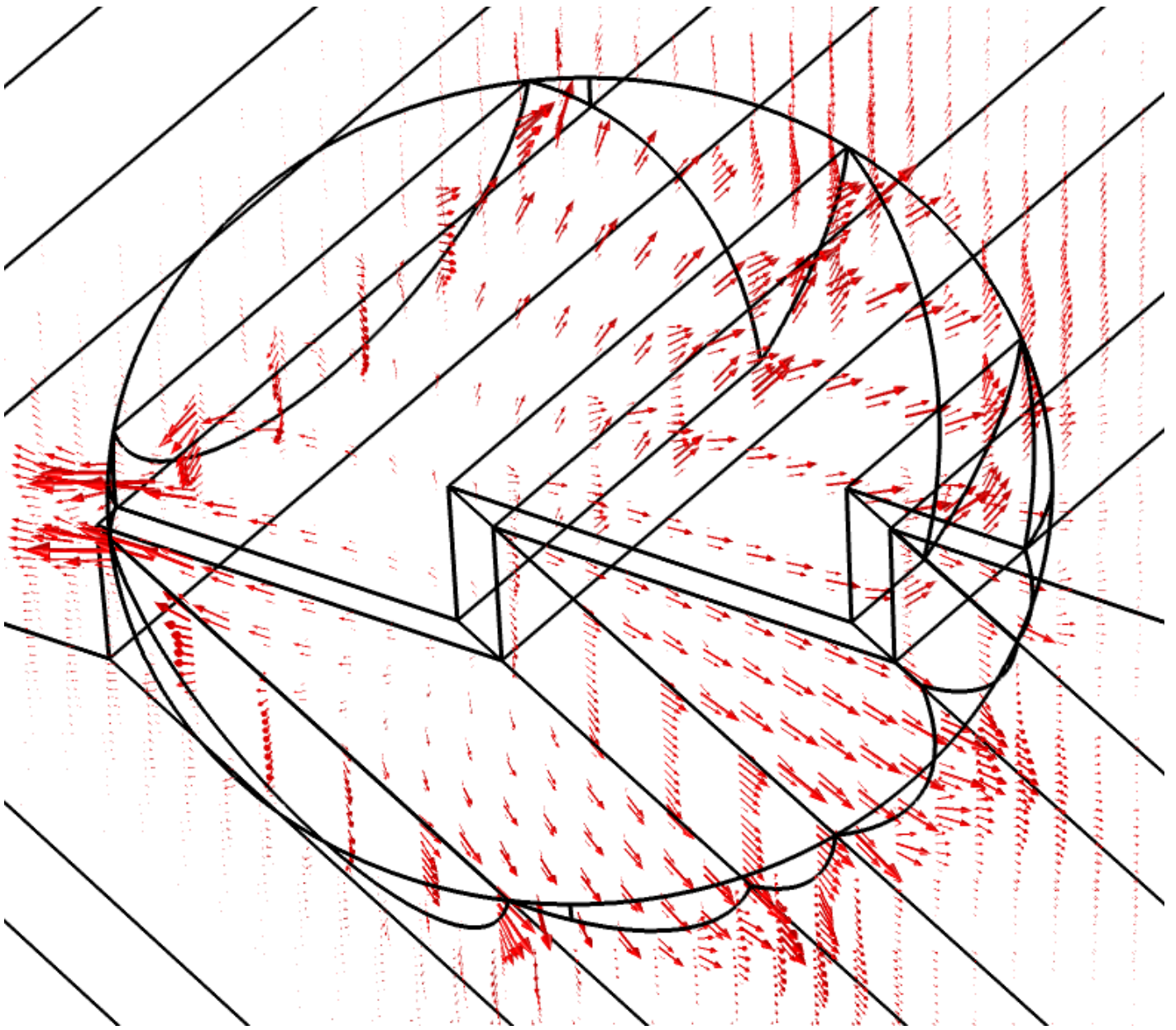
## Abstract

The Leidenfrost effect occurs when a droplet approaches a surface with a temperature much hotter than the boiling point of the liquid. Here, the underside of the droplet is instantly vapourised, allowing it to sit on a cushion of its own vapour, which grants the droplet virtually frictionless movement. A ratcheted surface will cause the droplet to self-propel across the surface due to viscous friction [1]. If two ratcheted surfaces are joined to form a herringbone pattern, the resultant geometry allows the droplet to self-propel, while also providing a self-centring aspect [2]. The droplet follows a damped oscillation path before settling at the centre of the herringbone. As the propulsion of Leidenfrost droplets is caused by the vapour layer, the speed of this can be measured to calculate the resulting force on the droplet. However, due to the barriers imposed by the herringbone pattern of the surface, the vapour flow is difficult to measure as the droplet crosses the centre. Therefore, simulations are used to model vapour flows at this point, which allows us to find the forces exerted and predict the droplet's path. The vapour phase above a herringbone ratchet was modelled in COMSOL Multiphysics® to calculate the shear force on the underside of the droplet. The inverse of the herringbone ratchet pattern was taken to represent the vapour phase sandwiched between the surface and the droplet. The droplet then had the teeth of the ratchet imprinted on the bottom to more accurately resemble a droplet in a Leidenfrost state on a herringbone ratchet. Finally, using the Laminar Flow interface, the flat sections of the droplet were set to be inlets for the vapour, and the edges of the simulation domain to be outlets. The simulation predicts how the force on the droplet changes as it transitions across the central boundary of the herringbone ratchet. This can then be used to inform a separate MATLAB® simulation that predicts the total motion of a droplet as it travels across a herringbone ratchet.

The frictionless nature of the Leidenfrost effect has uses from fluid transport to nanostructuring [1,3]. However, these droplets are difficult to control, where small variations in surface geometry can have large effects on the droplet's path. Therefore, simulations are used to predict droplet motion prior to experiments to help find the optimal surface geometry for the desired motion.

1. Lagubeau, G. et al. Leidenfrost on a ratchet. *Nature Physics* 7, 395-398 (2011).
2. Dodd, L. E. et al. Low-Friction Self-Centering Droplet Propulsion and Transport Using a Leidenfrost Herringbone-Ratchet Structure. *Physical Review Applied* 11, 034063 (2019).
3. Elbahri, B. M. et al. Anti-Lotus Effect for Nanostructuring at the Leidenfrost Temperature. *Advanced Materials* 19, 1262-1266 (2007).

## Figures used in the abstract



**Figure 1** : Figure: The velocity vectors of the vapour flow under a simulated droplet experiencing the Leidenfrost effect. Here the surface geometry has been imprinted on the underside of the droplet to mimic experimental conditions.