Droplet elasticity reduces the contact time on superhydrophobic surfaces

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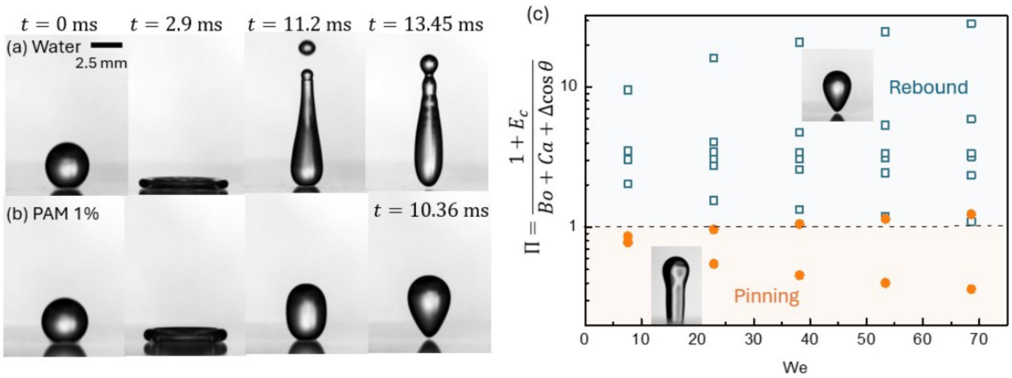
Droplet impact is a ubiquitous phenomenon in nature and industrial applications. Extensive research exists on the impact dynamics of Newtonian droplets, while the non-Newtonian scenario remains poorly explored. In this context, viscoelastic droplets have been proposed as an alternative to suppress droplet rebound. Although this is helpful for droplet deposition techniques, it can lead to surface damage on superhydrophobic surfaces. In a previous study, we demonstrated that at very high impact speeds, droplet rebound is actually possible due to the balance between elastic and adhesion forces [1].
In this work, we investigate the impact dynamics of shear-thinning viscoelastic droplets impacting at low speeds on superhydrophobic surfaces. Notably, besides complete rebound, viscoelastic droplets with viscosities up to 10,000 times that of water reduce the contact time on the surface by more than 20%. We attribute this effect to the elastic energy released as kinetic energy during droplet retraction, as previously proposed for yield-stress fluids [2]. We propose a theoretical model to explain this outcome based on the retraction of slender viscoelastic ligaments, where elastic stresses contribute to capillary stresses in the retraction process. Our experiments are complemented by numerical simulations that also demonstrate contact time reduction. We further derive a rebound criterion obtained from an energy-balance approach, which is in good agreement with experiments.

Keywords:
Complex fluids, Superhydrophobicity, Elasticity, Contact line dynamics.



(a) Water droplet impacting a superhydrophobic surface at an impact speed of 1 m/s. (b) Polyacrylamide droplet impacting at the same speed. (c) Rebound criterion based on the Elastocapillary, Bond, and Capillary numbers, together with the contact angle hysteresis to predic outcomes vs. Weber number.

References:

[1] D. Díaz, A. G. Balasubramanian, K. Amini, X. Li, F. Lundell, S. Bagheri, O. Tammisola. *Balloon regime: Drop elasticity leads to complete rebound.* Physical Review Research 8(2), 023022 (2026).
[2] M. H. Biroun, L. Haworth, H. Abdolnezhad, A. Khosravi, P. Agrawal, G. McHale, Y. Q. Fu. *Impact dynamics of non-Newtonian droplets on superhydrophobic surfaces.* Langmuir 39(16), 5793–5802 (2023).

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