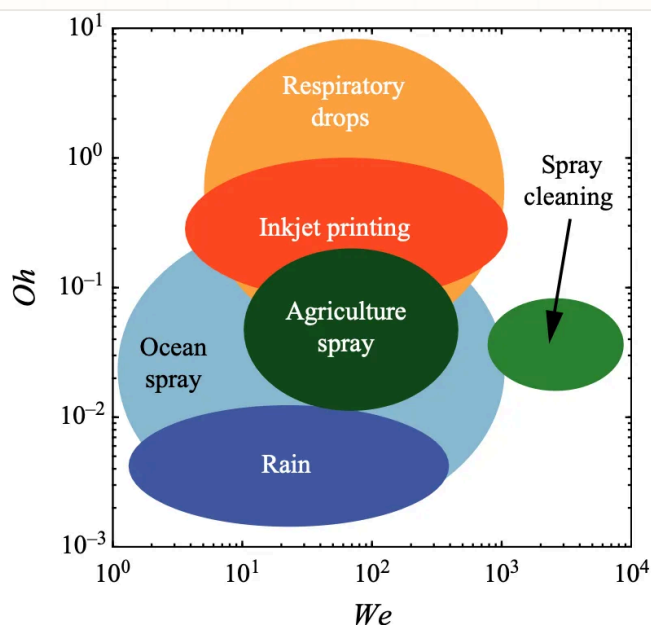
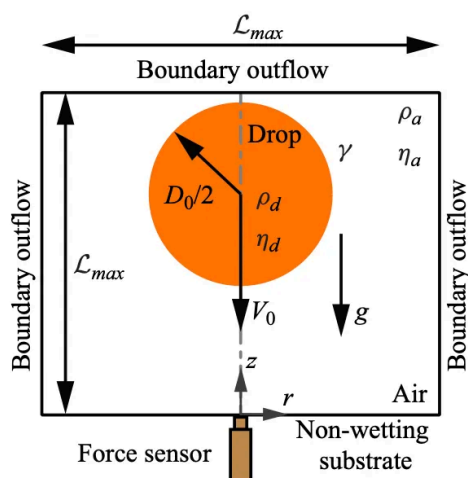




When a liquid drop hits a surface, the impact creates fascinating fluid dynamics that are crucial for applications ranging from inkjet printing to agricultural sprays. In this work, we uncover how a liquid's viscosity dramatically affects the forces generated during these impacts. Let's explore the key findings.



TL;DR

Viscosity alters the forces a liquid drop exerts when it strikes a non-wetting surface, shifting the balance from inertia-dominated (like water) to enhanced viscous effects (like honey). Two force peaks arise: one at the initial impact and another tied to the Worthington jet just before bounce. Dimensionless numbers (Weber and Ohnesorge) govern these regimes, showing why higher-viscosity drops can yield unexpectedly large forces. The findings unify scaling laws across viscosities, guiding applications in printing, agriculture, and beyond, and pointing to future inquiries on soft surfaces and non-Newtonian fluids.

The Basics: What Happens When a Drop Hits a Surface?

Key Point

On a non-wetting surface, a drop goes through distinct phases: impact, spreading, retracting, and sometimes bouncing off. During this process, the surface experiences varying forces that can now be precisely measured and predicted.

The impact process reveals two distinct force peaks:

1. An initial peak when the drop first hits
2. A second peak just before the drop potentially bounces off

What makes this especially interesting is how these forces change based on two key properties:

- Weber number ($We = \rho V_0^2 D_0 / \gamma$): Measures the dimensionless kinetic energy of the impacting drop.
- Ohnesorge number ($Oh = \eta / \sqrt{\rho \gamma D_0}$): Represents the dimensionless viscosity of the impacting drop.

The First Impact: A Tale of Two Regimes

First Peak Findings

The study reveals that the first impact force follows distinctly different patterns depending on the liquid's viscosity:

- For low viscosity liquids (like water), the force mainly depends on inertia
- For high viscosity liquids (like honey), viscous effects create stronger forces than expected

Low Viscosity Behavior

For liquids with low viscosity ($Oh < 0.1$), the first impact force (F_1) scales with the inertial force:

$$F_1 \sim \rho V_0^2 D_0^2$$

where ρ is density, V_0 is impact velocity, and D_0 is drop diameter. This relationship holds remarkably well for viscosities up to 100 times that of water!

High Viscosity Surprises

When viscosity becomes significant ($Oh > 0.1$), the force increases beyond what inertia alone would predict:

$$F_1 \sim \rho V_0^2 D_0^2 \sqrt{Oh}$$

This enhancement occurs because viscous forces resist the drop's deformation, leading to higher impact pressures.

The Second Peak: Worthington Jets and Bouncing

Worthington Jet

The second force peak coincides with a fascinating phenomenon called a Worthington jet - a thin liquid column that can shoot upward just before the drop bounces off.

The second peak reveals an intricate balance between different forces:

- For low viscosity and high speed impacts: Force scales with inertia
- For low speed impacts: Surface tension dominates
- At a special condition ($We \approx 9$, $Oh < 0.01$): A singular jet forms with surprisingly high forces

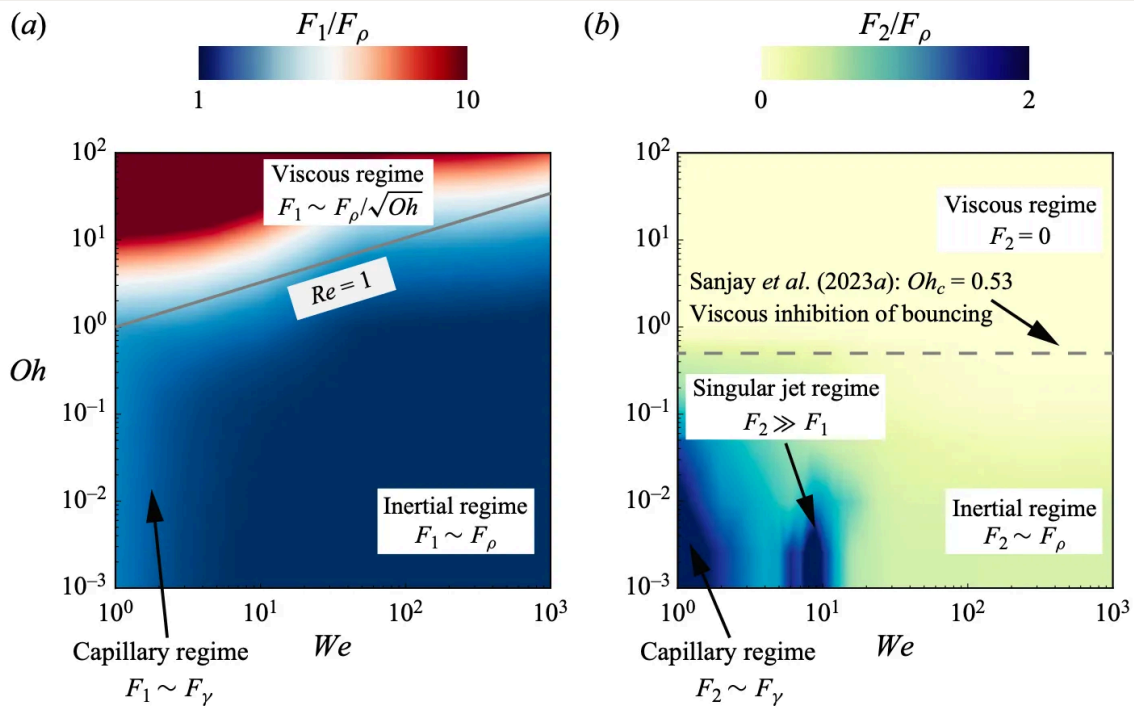


Figure 10. Regime map in terms of the drop Ohnesorge number Oh and the impact Weber number We to summarize the two peaks in the impact force by showing the different regimes described in this work based on (a) the first peak in the impact force peak amplitude F_1 and (b) the second peak in the impact force peak amplitude F_2 . Both peaks are normalized by the inertial force scale $F_\rho = \rho_d V_0^2 D_0^2$. These regime maps are constructed using ~ 1500 simulations in the range $0.001 \leq Oh \leq 100$ and $1 \leq We \leq 1000$. The grey solid line in (a) and dashed line in (b) mark the inertial–viscous transition ($Re = 1$) and the bouncing–no-bouncing transition ($Oh_c = 0.53$ for $Bo = 1$, see Sanjay *et al.* (2023a)), respectively.

Practical Implications

Applications

These findings have direct applications in:

- Inkjet printing: Controlling droplet behavior
- Agricultural sprays: Optimizing pesticide application
- Respiratory disease transmission: Understanding droplet impacts
- Industrial cooling: Enhancing heat transfer through controlled droplet impacts

Future Research Directions

This work opens several interesting avenues for future investigation:

- Unifying theories for maximum spread diameter across all viscosities
- Understanding impact forces on soft or compliant surfaces
- Extending findings to non-Newtonian fluids like polymer solutions

Technical Significance

For the technically inclined

The study provides a comprehensive framework for predicting impact forces through dimensionless numbers and scaling laws.

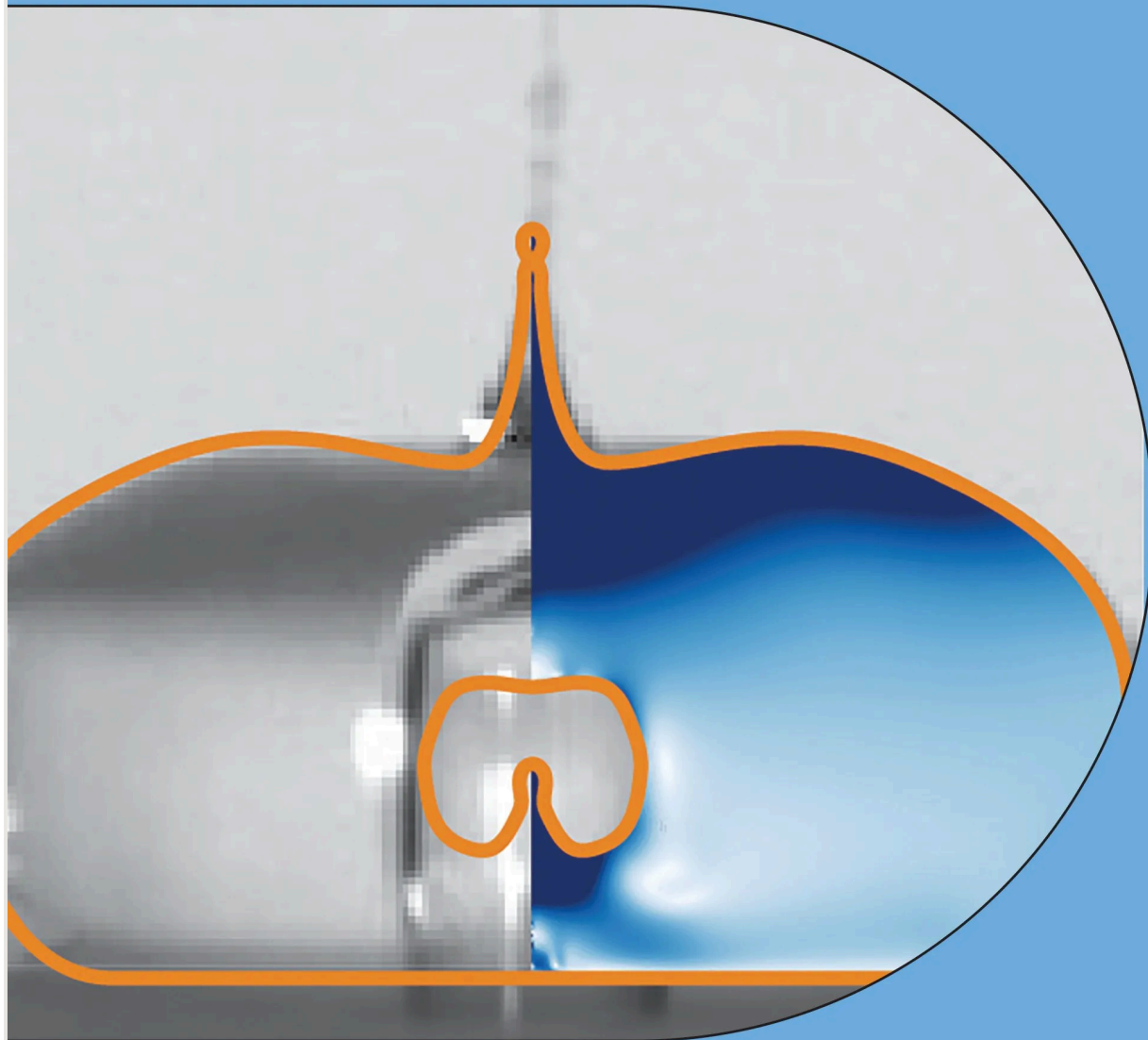
For researchers working in this field, the paper presents new scaling laws that unify previous observations and provide a foundation for future work. The careful experimental validation combined with theoretical analysis makes this a significant contribution to our understanding of drop impact dynamics.

Original Paper

V. Sanjay, B. Zhang, C. Lv & D. Lohse, The role of viscosity on drop impact forces, J. Fluid Mech., 1004, A6 (2025) [Open Access](#) .

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Sanjay *et al.* The role of viscosity on drop impact forces
on non-wetting surfaces



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