Rebound map for water drop impacts on tilted surfaces

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Abstract

Normal and oblique impacts of water drops on dry solid surfaces were studied experimentally, to investigate the conditions for drop rebound. Data from literature suggest that rebound of a drop from a surface can be achieved when wettability is low, i.e. when contact angles, measured at the triple line (solid-liquid-air), are high. However, no clear criterion exists to predict when a drop will rebound from a surface, and which is the key wetting parameter to govern drop rebound (e.g. the "equilibrium" contact angle, θ_{eq}, the advancing , θ_A, or the receding, θ_R, contact angles, contact angle hysteresis, $\Delta\theta$, or any combination of these parameters). As such, experimental tests were conducted to study impacts of millimetric water drops on different dry solid surfaces with variable wettability (i.e. with variable θ_A, θ_R, and $\Delta\theta$), on hydrophobic and superhydrophobic surfaces. The study was focused at performing a phenomenological investigation of drop impact, at understanding in which conditions a drop rebound, and at evaluating drop rebound time (time shift between impact and detachment of the drop from the surface). Impacts were performed on horizontal and tilted surfaces, to evaluate the effect of surface inclination on drop impact outcome. Experimental conditions were: impact speed in the range $0.8 < V < 4.1\text{m/s}$, constant drop diameter $D_0 = 2.55\text{mm}$ (constant), Weber numbers in the range $25 < We < 585$, Ohnesorge number $Oh = 0.0022$ (constant), surface advancing contact angles $108° < \theta_A < 169°$, and receding contact angles $89° < \theta_R < 161°$, and surface inclination angle $0° < \alpha < 80°$.

For normal impact tests, it was found that receding contact angle is the key wetting parameter to control drop rebound: drop rebound was observed only on surfaces with receding contact angle is higher than ~100°; also, drop rebound time decreases monotonically by increasing receding contact angle; a drop rebound map was proposed, accordingly. The analysis of oblique impacts onto tilted surfaces led to the definition of six different impact regimes (see Figure 1). Also, the following was found: on SHS ($\theta > 150°, \Delta\theta < 10°$), surface inclination generally enhances drop rebound and shedding from the surface, reducing drop rebound time up to 30%; on hydrophobic surfaces (with receding contact angles higher than ~100°), rebound was never observed for surface inclination up to 45°; the maximum inclination, $\alpha_{\max}$, at which drops rebound was found to depend on impact Weber number.

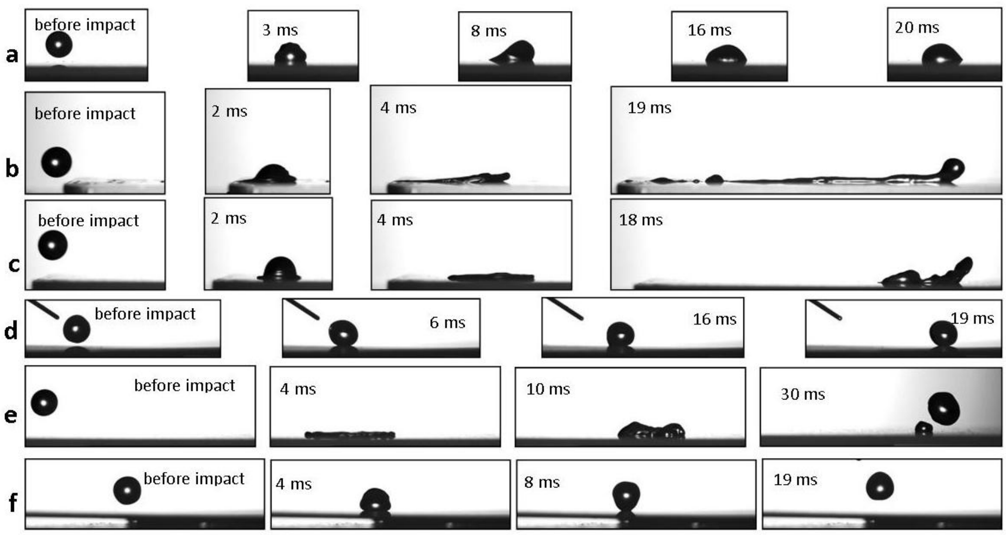

Figure 1: Outcomes of water drop impact onto various tilted substrates: (a) deposition, (b) slug, (c), sliding, (d) rolling, (e) partial rebound, and (f) rebound.

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