

Simultaneous Impact of Multiple Droplets on a Solid Surface

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Abstract This study develops a controlled generation of multiple droplets simultaneously to examine the physics of multiple droplet impacts on a solid surface. The developed droplet generator consists of a micro-controlled syringe pump connected with two needles. The control of the speed and steps of the motor of the syringe pump allows precise simultaneous ejection of a single droplet from each needle on demand. The droplet impacts on a solid substrate can lead to the interaction of the spreading lamellas between droplets to form an uprising liquid sheet. Simultaneous high-speed imaging from two views (front and side) of the sheet temporal evolution for three impact Weber numbers (We) of 55, 84, and 128 reveals the three-dimensional features, including the semicircular shape, instabilities, cusp formation and finger formation, of the sheet. The dependence of the height and periphery of the sheet on the impact Weber number is presented.

Keywords: Multiple droplet impact, Syringe pump, Central sheet, Weber number

1. Introduction

Numerous studies have established a good understanding of the physics of single droplet impact on solid surfaces [1]. However, multiple droplet impacts on surfaces, present in many applications, require more effort. When two droplets impact simultaneously on a solid surface with high kinetic energy, the spreading lamellas of the droplets interact and generate a central uprising sheet (Fig. 1) at their intersection line [2-5], which modifies the outcomes of equivalent non-interacting single droplet impacts. This liquid sheet is barely investigated through experiments due to difficulties in generating multiple droplets simultaneously [2]. Roisman et al. [4] reported a theoretical model to estimate the central sheet height (H_s) with time (t). Recent studies [2, 5] experimentally investigated the time-resolved evolution of the central sheet with a single side view of the sheet.

However, simultaneous imaging of the sheet evolution from different views is important [2]. This study presents an experimental setup for a systematic study of simultaneous droplet impacts on solid surfaces.

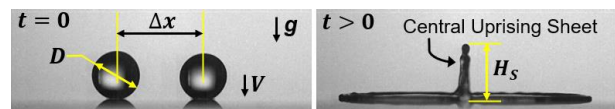


Fig. 1. Simultaneous impact of two droplets.

2. Experimental Setup and Methods

A syringe pump was developed with a microcontroller (Arduino) system. The control system adjusted the speed and steps of the pump motor to precisely deliver the liquid to the needles (Fig. 2). A certain amount of distilled water was dispensed at each needle generating simultaneous single droplet ejections with minimum oscillation. The ejected droplets were then allowed to impact on a smoothly polished Perspex plate.

Two high-speed cameras (Photron, FASTCAM APX RS and FASTCAM SA1.1) were used at 9000 fps with spatial resolutions of 0.03- and 0.04-mm pixel⁻¹ for the front and side views, respectively. The droplet diameters (D), spacing between droplets (Δx), impact velocity (V), and the height of the uprising sheet (H_s) were determined by image analysis with MATLAB. D and Δx were constant at 3.12 ± 0.05 mm and 5.5 ± 0.1 mm, respectively. The impact process depends on the Weber

number ($We = \rho DV^2 / \sigma$, where ρ is the liquid density and σ the surface tension), which was varied by adjusting the droplet release height.

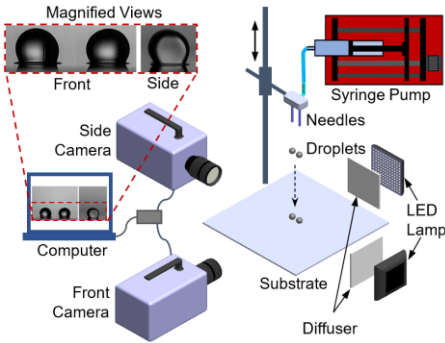


Fig. 2. Schematic of the experimental setup.

3. Results and Discussion

Figs. 3 and 4 show instantaneous images at different dimensionless times $\tau (= tV/D)$ of the impact process for three different Weber numbers. All cases have high impact kinetic energy, generating a central liquid sheet with increasing height up to a certain time and then decreasing due to gravity, remaining vertical (Fig. 3).

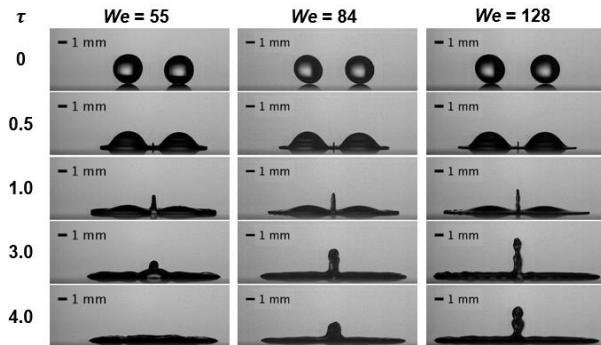


Fig. 3. Central sheet Evolution (Front View)

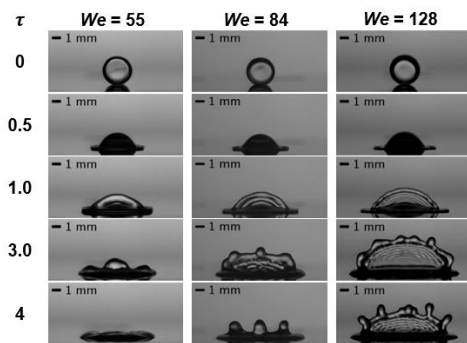


Fig. 4. Central sheet evolution (Side View)

The side view images (Fig. 4) show the central sheet characteristics, such as a semicircular

shape of the growing sheet (up to $\tau \approx 1$), rim formation at the sheet periphery, instabilities and multiple cusp formation at the sheet rim during its vertical retraction. The sheet rim instabilities increase with We and the cusps form fingers for higher We . Fig. 5 shows the temporal evolution of dimensionless sheet height ($H_{S,nonD} = H_S/D$) with impact Weber number.

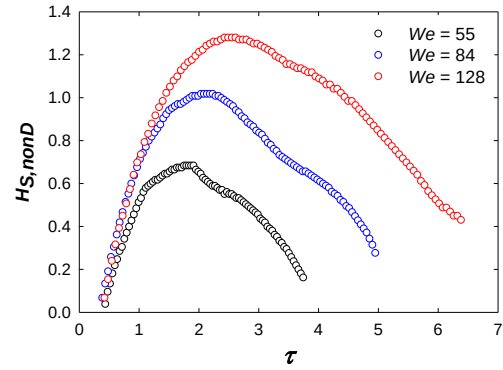


Fig. 5. Effect of We on central sheet height

4. Summary

The developed droplet generator delivers reliably simultaneous droplet surface impacts. The three-dimensional central uprising sheet is affected by the impact Weber number.

References

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