Transient Impingement Phenomenon of Two Droplets Upon a Solid Wall in Sequence

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ABSTRACT

Sprays are an important application in industrial process such as spray cooling, spray forming, spray coating, spray scrubbing, and ink-jet painting, and so forth. In a practical spray system, liquids are injected from nozzles and then fragmented due to interaction between the gas phase and the liquid phase such as turbulence, cavitation, and aerodynamic forces [1]. Thereafter, a considerable number of droplets are generated and dispersed in the gas phase. In some spray systems, the performances of sprays, say, spray cooling, spray coating, and ink-jet painting, are highly related to the consecutive impingements of droplets upon a solid wall. When the mechanisms of droplets impacting on a solid surface are examined in detail, soon after the first droplet impinges the wall, a liquid film is formed. Afterward, for the coming second droplet the phenomenon becomes the collision between a liquid droplet and a liquid film. It follows that either a droplet퇼 impact on a solid substrate or impingement of a droplet upon a liquid film is a physically intrinsic behavior in spray applications.

In the past, to recognize detailed fluid mechanisms happened between the liquid phase and the solid phase, numerous studies concerning impact of droplets on a solid surface have been carried out and a variety of methods and models have been developed. These methods include the marker-and-cell (MAC) [2], volume of fluid (VOF) [3], finite element [4], and overall energy balance (OEB) [5] techniques, and so on. As far as a droplet colliding with a liquid film or two droplets impacting upon a solid substrate is concerned, relatively little research has been performed; in practice, however, they are closely relavant to the sprays applications.

To figure out detailed deformation and spreading fluid dynamics for two droplets in tandem consecutively impacting upon a solid wall, a numerical method is developed to predicted the physical phenomena in the present study. In the developed method, a level set function [6] is applied to deal with interfacial fluids properties such as densities and viscosities. Meanwhile, the SIMPLER algorithm [7] is followed to solve the pressure and velocity fields of the gas phase and the liquid phase. The computational domain is extended to 20 and 8 radiuses of droplet in the X and Y directions, respectively, with the former and the latter having 201 and 81 points. In order to ensure the validity of the developed numerical method, Fig. 1 first demonstrates the distributions of central height and radius of a spreading droplet with respect to time where the droplet Reynolds number and the

Weber number are 200 and 2.15, respectively. Comparison of the numerical predictions and experimental results [8] are shown in the figure as well, In the predictions, though the effect of wall roughness is not considered, the numerical results are in good agreement with the experimental measurements, revealing that the numerical method developed presently is reliable.

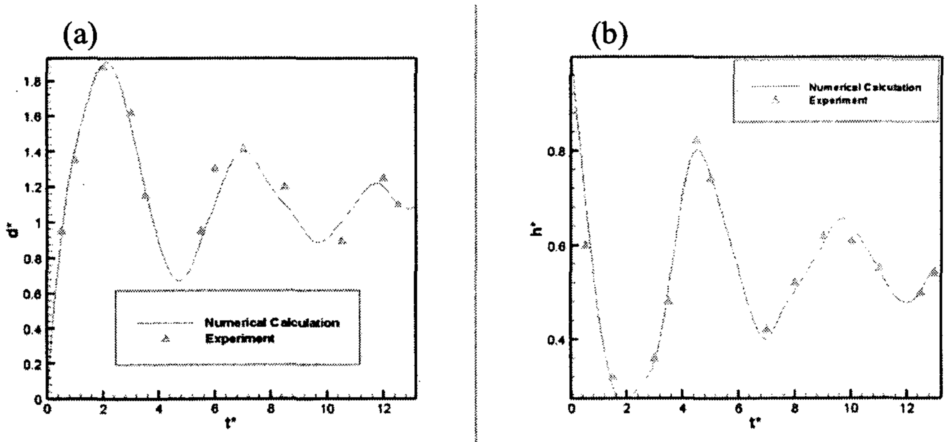

FIG. 1. Distributions of (a) central height and (b) radius of spreading droplet with respect to time (*Re*=200，*We*=2.15).

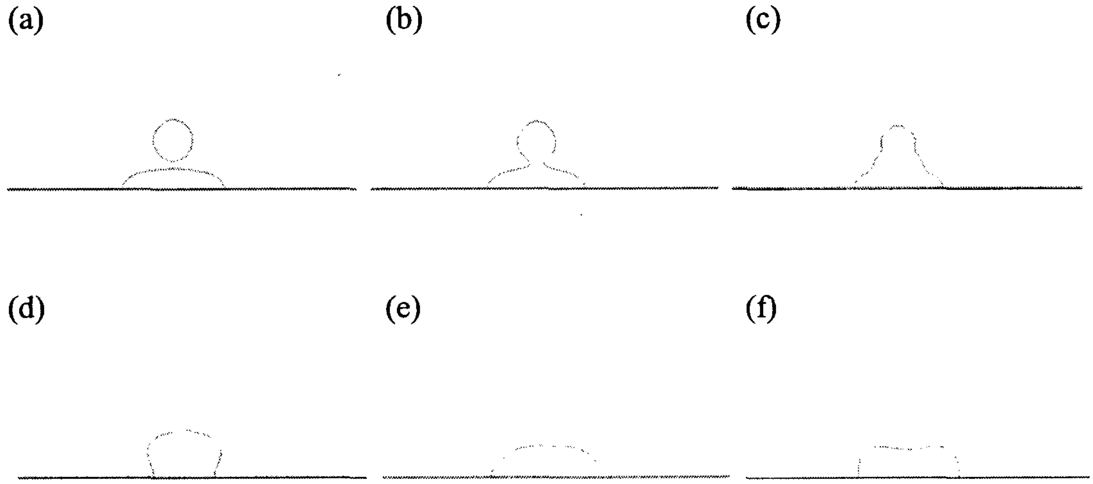

FIG. 2. Deformation evolution of two droplets in tandem collision with a solid wall at dimensionless times of (a) 3100, (b) 3200, (c) 3500, (d) 4000, (e) 6500, and (f) 7500 (*Re* = 200, *We* = 2.15).

Subsequently, deformation evolution of two droplets in tandem colliding with a solid wall at various dimensionless times is presented in Fig. 2. The individual droplet휠 Reynolds number and Weber number are 200 and 2.15 as well. The inital positions of the front and the rear droplets? center are away from the solid wall 1.2 and 3.2 radiuses, respectively. Fig. 2a first sketches the surface contours of the two droplet prior to the second droplet impacting the first one. Of course, the first droplet휠deformation is a consequence of inertial force. Meanwhile, the rear droplet is approaching the first one. Fig. 2b demonstrates the inital behavior at the interface for the rear droplet merging into the front droplet. After that, on account of the effect of surface tension, Fig. 2c clearly depicts that the two-droplet interface extends outward. It is known that, while the two droplets merge together and deform, part of the kinetic energy of the two droplet will be dissipated, resulting the the effect of viscous force. In other words, by virtue of the interaction among internal force, surface tension, and viscous force, the merged droplet wil spread alony the horizental direction and osscilate along the vertical direction, as shown in Fig. 2d-2f. In a word, in the inital period the inertial force and surface tension dominate the fluid dynamics; nevertheless, in view of the progressively growing effect of the viscous force, the merged droplet tends to decay the osscilation and eventually reaches a steady state.

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