EXPERIMENTAL OBSERVATION OF LIQUID DROPLET IMPINGEMENT UPON SUPER-HEATED WALL WITH HIGH WEBER NUMBERS

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Impingement of liquid droplets upon heated wall is of great importance in many industrial processes; spray cooling, fuel injection, and powder production. The droplet impingement has been studied by many researchers[1,2,3]. Based on the results, several numerical models of spray-wall interaction have been developed[4,5]. However there are still many unsolved problems. In the present study dynamic behavior of individual water droplet, which impinged on super-heated wall with high Weber number, was investigated in detail. The following were deduced; there was a transition regime from nucleate boiling to film boiling, the droplet showed a peculiar breakup behavior in the transition regime.

Experimental Setup

Experimental setup is shown schematically in Fig.1. Using syringe pump and PZT driven droplet generator, uniform-sized water droplets were produced one by one. The droplet fell gravitationally and impinged on the target, which was heated electrically. The target was the end of a brass cylinder 40mm dia. Surface of the target was burnished preparatory to the observation. The setup provided variations in impingement angle and impingement velocity of droplet. Behavior of droplet was observed by flash photography and high-speed video camera. Range of experimental investigations is listed in Table 1.

Experimental Results and Discussions

Ensuing the droplet impingement upon super-heated wall, the droplet spread into circular liquid film, then the liquid film broke up (or receded) and detached from the wall. Breakup behavior of the droplet did not depend upon the impingement angle so much, though the liquid film slid over the wall during the breakup processes. Fig.2 shows four representative behaviors of droplets. We_n is Weber number based on the normal component of impingement velocity ($We_n=\rho_l V_n^2 d/\sigma_l$; $V_n=V \sin\theta$, σ, μ_l, and ρ_l are surface tension, liquid viscosity and density, respectively). When We_n was sufficiently small, the droplet rebounded, as shown in Fig.2 type-A. At slightly higher We_n, the droplet rebounded forming a satellite droplet, type-A'. When We_n was larger, the droplet broke up into a large droplet and several small droplets, type-B. At still higher We_n, the droplet splashed to form many small droplets, type-C.

The breakup behavior also depended upon the wall super-heat. When the wall temperature was lower than Leidenfrost point ($T_w-T_s\leq125$K), conventional nucleate boiling phenomenon was observed after the film-spreading phase. When the wall temperature was sufficiently high ($T_w-T_s\geq250$K), the liquid film was smooth and transparent, as shown in Fig.3(b). The liquid film should be separated from the heated wall by vapor layer. Within the intermediate range of wall super-heat, a peculiar phenomenon was observed during the film-spreading phase. Many fine droplets were spouted from the liquid film with short sound of sizzle. The liquid film was milky and broke up rapidly, as shown in Fig.3(a). There should be many fine bubbles in the liquid film, and the fine droplet ejection should be due to collapse of the bubbles. Fig.4 shows map of observed breakup patterns. Except for the range of We_n smaller than 30, the fine droplet ejection with sizzle was observed in the range of wall super-heat from 150K to 225K, and the range of super-heat did not depended upon We_n as shown in Fig.4. Critical We_n for transition of breakup pattern showed stair-step increase with disappearance of the fine droplet ejection.

Fig.5 shows resident time, τ, of droplet upon the heated wall. In the range of intermediate wall super-heat, where the fine droplet ejection with sizzle was observed, the resident time of droplet was shorter than that in high super-heat range. That is, the breakup of liquid film was promoted by the fine droplet ejection. Fig.6 shows dimensionless resident time, τ*, of droplet. An empirical correlation of τ* was proposed as shown in Fig.6. Fig.7 shows maximum spreading diameter, D_{max}, of the liquid film. The maximum spreading diameters did not depend so much upon the wall super-heat, increased with increase of We_n and almost agreed with previous empirical correlation [1] for low Weber numbers.

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Table 1 Experimental condition.

Test liquid	Distilled water
Material of target	Brass (Burnished)
Initial temperature of liquid	25 ± 3 °C
Saturation temperature; T_s	100 °C
Wall temperature; T_w	200 – 450 °C
Diameter of droplet; d	1.5, 2.0, 3.0mm
Impingement velocity; V	1.0, 2.0, 4.7 m/s
Impingement angle; θ	π/2, π/3, π/4

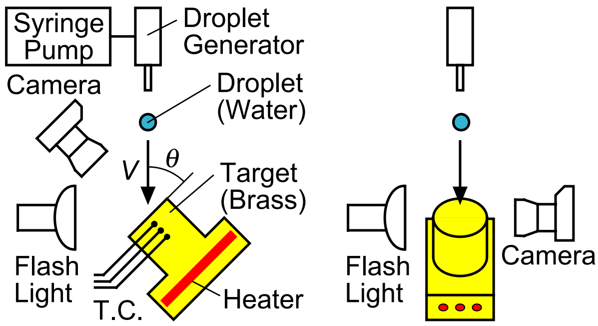

Fig.1 Experimental setup.

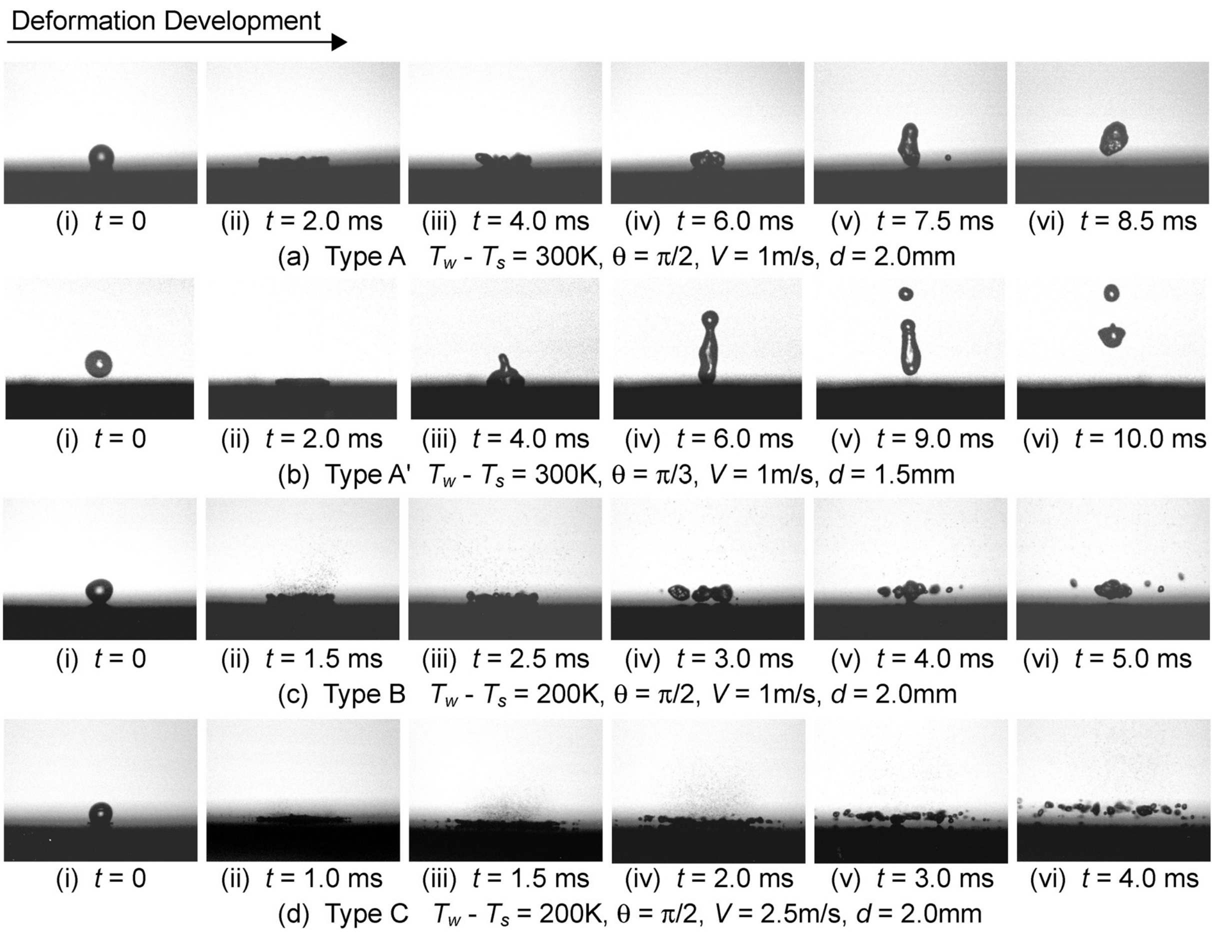

Fig.2 Flash photographs of droplets impinged upon heated wall, showing typical breakup patterns.

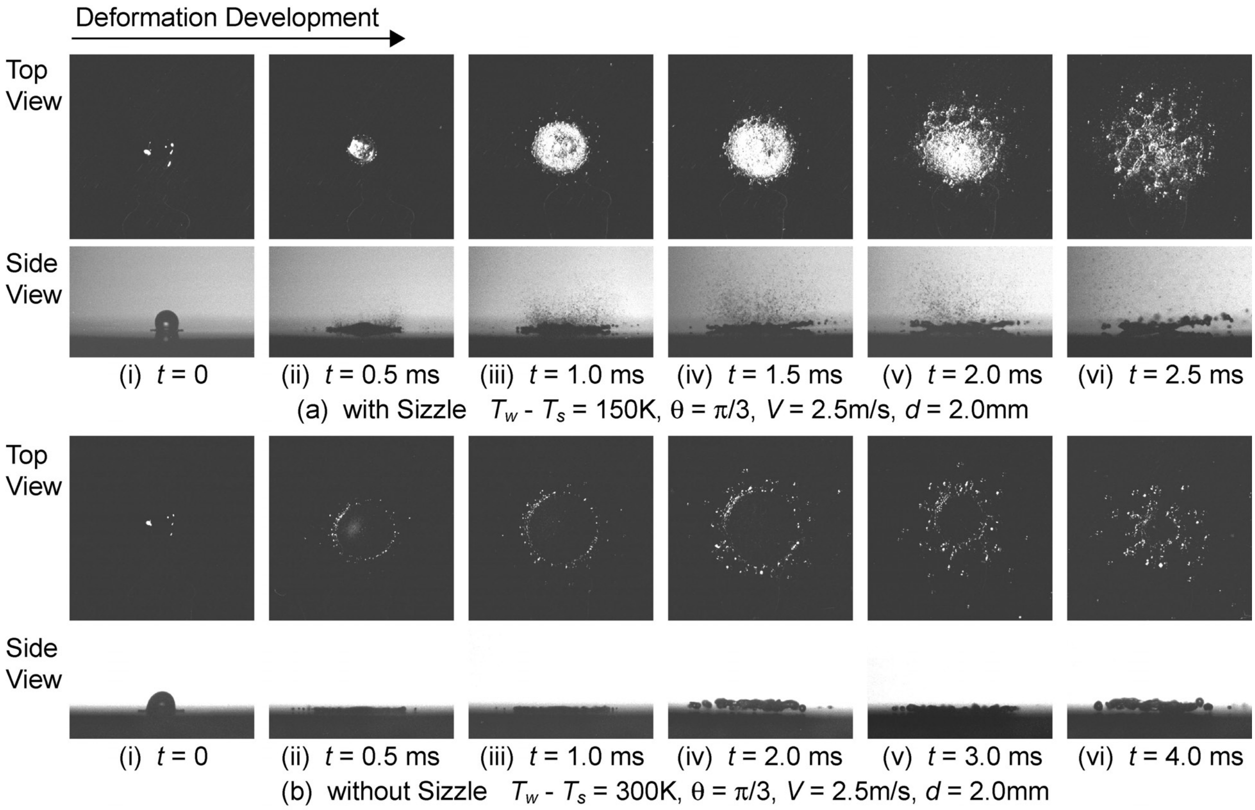

Fig.3 Two views of breakup behavior, showing the sizzling case and the non-sizzling case.

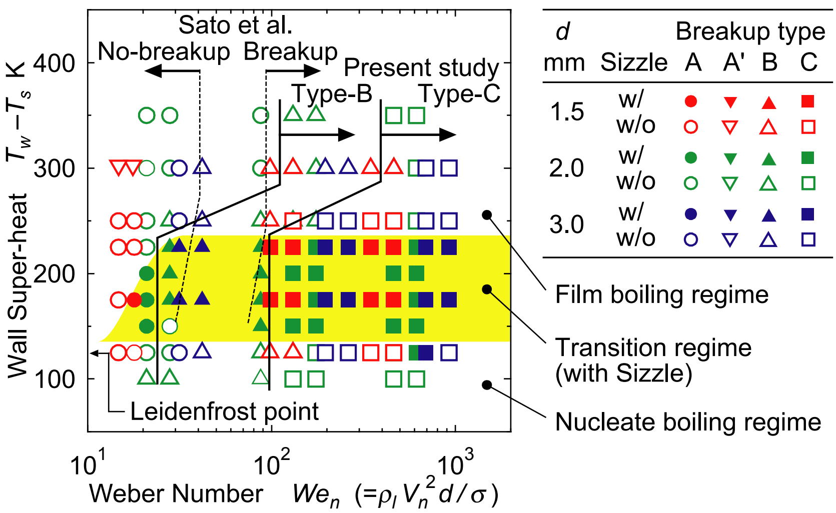

Fig.4 Map of observed breakup patterns.

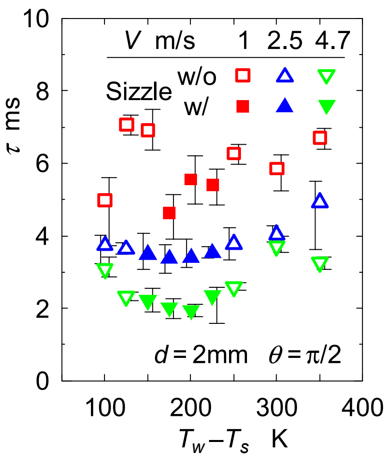

Fig.5 Resident time of droplet.

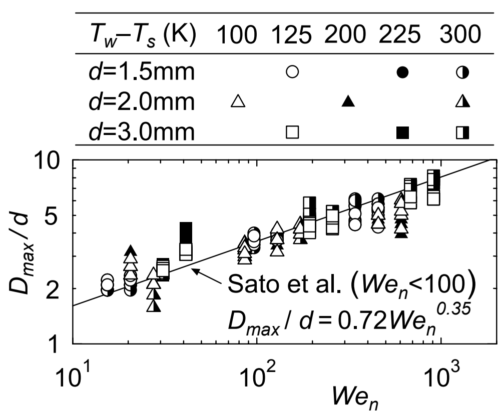

Fig.7 Maximum spreading diameter of liquid film.

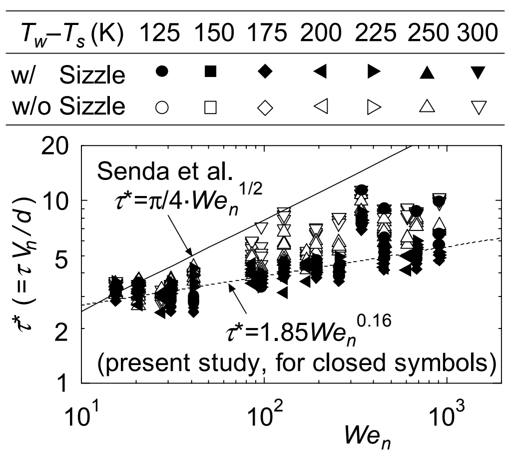

Fig.6 Dimensionless resident time of droplet.