Single Droplet Heat Transfer through Shallow Liquid Pools

Henry Vu[1], Guillermo Aguilar[1*] and Richard Jepsen[2]
[1]University of California, Riverside, CA 92521
[2]Sandia National Laboratories, Albuquerque, NM 87185

Abstract

Many studies exist examining the underlying physics behind single droplet impact splashing and cooling. However, despite its practical importance, little information exists concerning the influence of liquid surface films on resultant heat transfer. In this study, water droplet impact behavior into quiescent liquid pools was visualized using a high-speed video camera set at 3000 fps. The impacting droplets were dyed in order to promote contrast and visualization. Pool depths ranging from 0 to twice the droplet diameter were used in order to assess its influence on impact dynamics. Additionally, heat transfer was measured from an epoxy block substrate. The epoxy block surface was heated to 42˚C to induce heat transfer with the impinging droplet which was kept at room temperature. Transient surface temperature history was recorded with a flat, fast-response thermocouple embedded at the substrate surface. Heat flux and overall heat extraction was subsequently calculated using Duhamel's Theorem. Droplet diameter and velocity were varied from 2.5-3.7 mm and 0.5-2 m/s, respectively.

It was found that with dry surfaces, heat transfer was highest and could be divided into a convective phase in which the droplet is initially impacting and spreading, and a conductive phase where the droplet becomes relatively stagnant while still cooling the surface. Since the impacting droplets must penetrate through the liquid pools to reach the substrate, heat transfer was significantly reduced for cases with pools. However, some unusual convective phenomena were observed for cases in which the pool depth was comparable to the droplet diameter. Cooling could be slightly enhanced through convective eddy formation which is inhibited in thin pools. Also, deeper pools allowed for separate, isolated cooling periods in which the impacting droplet contacted the substrate surface multiple times through oscillation of the pools surface. The results provide insight into the processes occurring during spray cooling.

Key words: droplet splash, heat transfer, spray cooling

[*]Corresponding author, gaguilar@engr.ucr.edu