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THE EFFECT OF SURFACE TENSION AND CONTACT ANGLE ON THE SPREADING OF A DROPLET IMPACTING ON A SUBSTRATE

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ABSTRACT

The spreading of a water droplet impacting on a flat solid surface was studied using both numerical models and experiments. Surface tension was varied in experiments by adding traces of a surfactant to water. Droplet impact was photographed, and liquid-solid contact diameter and contact angle measured from photographs. A numerical solution of the Navier Stokes equation using a modified SOLA-VOF method was used to model droplet deformation during impact. Measured values of contact angle were used as a boundary condition for the numerical model.

Under the condition of low We numbers (We<40) impacting droplets spread on the surface until surface tension forces overcame liquid inertia, after which they recoiled off the surface. Decreasing surface tension did not affect droplet spreading, but did reduce the height of recoil. Comparison of computer generated images of impacting droplets with photographs showed that the numerical model correctly modelled droplet shape during deformation. Accurate predictions were obtained for droplet contact diameter during spreading, and at equilibrium. The model overpredicted droplet contact diameters during recoil. When the contact angle was assumed constant in the model, equal to the measured equilibrium value, predictions were less accurate.

INTRODUCTION

A study of the impact dynamics of liquid drops on a solid surface is required in modelling industrial processes such as spray cooling of hot surfaces, fire extinguishment by sprinkler systems, plasma coating, spray forming, and pesticide spraying. Simple analytical models of droplet impact have been proposed (e.g., Madejski 1976; Chandra & Avedisian 1991; Karl, Anders & Frohn 1993), based on an energy balance that equates initial droplet kinetic energy to the change in surface energy due to droplet deformation, and the work done in overcoming liquid viscosity during impact. Bennett & Poulikakos (1993) have reviewed several such models and discussed their use in predicting the maximum diameter of droplet spread, after which further spreading is restrained by surface tension and viscous forces. However, calculations of heat transfer between the surface and droplet require detailed information about droplet shape during impact, which can be obtained only by a complete numerical solution of the continuity, momentum and energy equations.

Harlow and Shannon (1967) were the first to obtain a numerical solution to the problem of droplet impact, using the so called "Marker-and-Cell" (MAC) finite difference method to solve the Navier-Stokes equations. They neglected the effect of surface tension and viscosity, so that their results were applicable only to the initial stages of droplet impact when these forces are negligible compared to inertial effects. Their solution could not predict the maximum extent of liquid spread, but proved useful in research on erosion of turbine blades by high speed impinging droplets, where it predicted peak liquid pressures immediately after impact (Huang, Hammitt & Yang 1973; Pidsley 1983). Modelling heat transfer within the droplet required modifications to the MAC code to include surface tension and viscous effects, which was done by Tsurutani