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# DROPLET IMPACT AND SOLIDIFICATION : COMPARISON OF EXPERIMENTAL AND NUMERICAL RESULTS

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## ABSTRACT

Impact and solidification of tin droplets on a flat stainless steel substrate was studied using both experiments and numerical simulation. In the experiments tin droplets (2.1 mm diameter) were formed and dropped onto a stainless steel surface whose temperature was varied from 25°C to 240°C. Impact of droplets was photographed, and evolution of droplet spread diameter and liquid-solid contact angle measured from photographs. A complete numerical solution of the Navier-Stokes and energy equations, based on a modified SOLA-VOF method, was used to model droplet deformation and solidification and heat transfer in the substrate. Measured values of liquid-solid contact angle were used as a boundary condition for the numerical model. Values of the thermal contact resistance at the droplet-substrate interface were estimated by matching numerical predictions of substrate temperature variation and droplet contact diameter with experimental measurements. Comparison of computer generated images of impacting droplets with photographs for all three cases showed that the numerical model correctly modeled droplet shape during deformation and solidification.

## INTRODUCTION

An understanding of the fluid flow and heat transfer that occurs during the impact, spreading, and solidification of molten metal droplets on a solid substrate is important in a number of engineering applications. Typical examples include thermal spray coating, spray forming, soldering and rapid solidification processing. Several investigators (Moreau et al. 1992a, 1992b, 1995; Vardelle et al 1995; Bianchi et al 1995) have studied the deposition of individual droplets in a plasma spray on a solid surface, and concluded that the properties of the coatings are sensitive to the shape and cooling rate of splats formed by molten droplet impact on the substrate. To be able to predict the effect of parameters such as droplet size, velocity and temperature on splat formation, several numerical models have been developed to simulate impact and solidification of molten droplets on a cold surface (Trapaga et al 1992; Liu et al 1993; Pasandideh-Fard and Mostaghimi 1996; Waldvogel and Poulikakos 1997).

When a molten droplet collides with a cold substrate, it simultaneously starts to spread and solidify. Therefore, the resulting momentum and heat transfer (including phase change) are coupled, and occur within time-varying boundaries. Bennett and Poulikakos (1994) and Kang et al. (1994) studied droplet deposition assuming that solidification starts only after droplet spreading is complete, when the splat is in the form of a disc. The validity of such an assumption depends on the rate of solidification following droplet impact. Zhao et al. (1996a, 1996b) studied, using both numerical models and experiments, heat transfer and fluid dynamics during collision of a liquid droplet on a substrate in the case that there is no solidification. Liu et al.(1993), Trapaga et al.(1992), and Bertagnolli et al. (1995) used finite difference models to study the simultaneous spreading and solidification of impacting droplets. They assumed that the substrate was isothermal, and neglected any thermal contact resistance at the liquid-solid interface. The liquid-solid contact angle was assumed to be constant in these studies, with an arbitrarily assigned value. Pasandideh-Fard et al. (1996) have shown, however, that the value of the contact angle can significantly influence model predictions. Pasandideh-Fard and Mostaghimi (1996) modelled droplet impact assuming heat transfer in both the droplet and substrate to be by one-dimensional heat conduction. They studied the effect of varying thermal contact resistance between the droplet and substrate. Waldvogel and Poulikakos (1997) used a finite element model to simulate spreading and solidification during droplet