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3D MODEL OF THE IMPACT AND SOLIDIFICATION OF A DROPLET ON A SOLID SURFACE

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A three-dimensional model has been developed to simulate the impact dynamics, heat transfer and solidification of a droplet onto a flat substrate. The model is an extension of the model developed by Bussmann et al. [1] and combines a fixed-grid control volume discretization of the fluid flow and energy equations with a volume tracking algorithm to track the droplet free surface and an improved fixed velocity method to track the solidification front. Surface tension is modeled as a volume force acting on fluid near the free surface. Contact angles are applied as a boundary condition at the liquid-substrate and the liquid-solid contact lines. Energy equations in the liquid and solid phases of the droplet are solved using the Enthalpy method. Within the substrate there is only conduction heat transfer. Thermal contact resistance at the droplet-substrate interface is included in the model. We studied the deposition of tin droplets on a stainless steel surface using both experiments and numerical simulations. The results of two scenarios are presented: the normal impact of a 2.7 mm tin droplet at 1 m/s, and the oblique impact of a 2.2 mm tin droplet at 2.35 m/s onto a 45° incline. The images obtained from numerical model are compared with photographs.

INTRODUCTION

Modeling industrial processes such as spray cooling of hot surfaces, spray forming, deposition of solder bumps on printed circuit boards, and thermal spray coating requires an understanding of the impact dynamics, heat transfer, and solidification of liquid drops on solid surfaces. Since it is often easier and more economical to optimize spray application parameters using a computer model rather than experiments, several numerical models have been developed to simulate droplet impact. Most of these works [2-6] focused on the axisymmetric, or 2D impact of a droplet on a surface. Far less has been published on droplet impact which is not axisymmetric, and thus must be considered three-dimensionally. Zheng and Zhang [7] developed a 3D adaptive level set method for moving boundary problems and applied the model to droplet spreading and solidification. Validation of their model results against experiments was not reported. Moreover, thermal contact resistance at the substrate surface, and contact angle, especially of the liquid phase on its own solid, was not considered. Bussmann et al. [1] developed a 3D numerical model of free surface flows. They presented the results for two scenarios of 3D droplet impacts: the impact on an incline and the impact on a sharp edge. The model was validated by a comparison between the numerical results and experimental photographs.

The model of Bussmann et al. [1], though three-dimensional, did not consider heat transfer and phase change during the impact and could only deal with relatively simple substrate shapes that follow the

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