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SPLAT SHAPES IN A THERMAL SPRAY COATING PROCESS: SIMULATIONS AND EXPERIMENTS

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ABSTRACT

A 3D computational model of fluid flow and heat transfer including solidification was developed. The model was used to simulate the impact of nickel particles on a stainless steel substrate in impact conditions measured experimentally (60 µm particles diameter, 73 m/s impact velocity, particles 150°C above their melting temperature). We considered two cases where the initial substrate temperature was 290°C and 400°C. Numerical results were compared with experimental photographs taken at the same conditions. Different splat shapes obtained numerically were comparable with those obtained experimentally. For the substrate initially at 290°C, the final splat had a bulk with fingers around it (star-like shape). Fast growth of solidification was found to be the cause of particle splashing. When the substrate temperature increased to 400°C, the final splat was a flat disk with a round shape. Numerical model showed that the change of splat shape for the two cases was due to a different value of contact resistance at the substrate surface. At a higher substrate temperature, the contact resistance was higher resulting in a lower rate of heat transfer to the substrate and a lower growth of solidification inside the particle. Good qualitative agreement between the results of the numerical model and experimental photographs demonstrated the model to be well suited for studying particle impact in a thermal spray coating process.

INTRODUCTION

Thermal spray is a term used to describe various processes that utilize a heat source to convert powders of metallic and nonmetallic materials into a spray of molten particles that are deposited onto a substrate. This technology is commonly used to apply coatings to substrates, to protect against wear, corrosion, and thermal shock. Physical properties of thermal spray coatings, e.g. porosity, are sensitive to a large number of process parameters (such as in-flight particle size distribution, velocity, temperature and degree of solidification; substrate material and temperature) which are optimized by trial and error (Vardelle et al 1995). Better control of the process requires a fundamental understanding of the fluid flow and heat transfer that occurs during the impact, spreading, and solidification of molten droplets.

Several numerical models of droplet impact on a surface including heat transfer have been developed. Most of these works (Pasandideh-Fard and Mostaghimi 1996; Zhao et al 1996; Bertagnolli et al 1997; Waldvogel and Poulikakos 1997; Pasandideh-Fard et al 1998) 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. The 2D/axisymmetric models cannot model 3D aspects of the flow, for example fingering, during the spreading. Modeling droplet impact and solidification in a thermal spray process, where droplet splashing and fingering occur, requires a 3D model. Bussmann et al (1999) 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 impacts were considered to be isothermal; no energy equation was solved in the model.

The objectives of our study were: to extend the 3D computational model of Bussmann et al (1999) to include heat transfer and solidification, and to use the model to study the splat shapes during the impact of nickel particles on a stainless steel substrate in impact conditions measured experimentally.