NUMERICAL SIMULATION OF THE SPREADING AND SOLIDIFICATION OF A DROPLET IN PLASMA SPRAY PROCESS

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Abstract

Purpose: To perform a numerical simulation of the impingement process, including flattening and simultaneous solidification, of a liquid droplet onto a solid surface.

Methods: The numerical solution for the complete Navier-Stokes equations is based on the modified SOLA-VOF method using rectangular mesh in axisymmetric geometry. For the solidification part of the deformation process, based on a one dimensional *Stefan* problem in heat conduction, a numerical procedure has been developed.

Results: An extensive set of computations for different cases has been carried out to study the complete deformation process and the importance of solidification in spreading process. The effect of solidification becomes more important for high Reynolds and low Stefan numbers. We found a good agreement between our results and the available data.

Conclusions: The simultaneous solidification has an important effect on the impingement process in plasma spraying such that the two phenomena of flattening and solidification can not be studied separately.

Introduction

Thermal plasma spraying has been receiving increasing attention over the last three decades. The industrial significance of this process lies in the possibility of the deposition of melted and accelerated micron sized particles upon a substrate, in order to produce a strong mechanical and anticorrosive coating on preshaped parts. Flattening and solidification of these particles impinging onto the substrate surface are two important processes controlling the coating quality. These two phenomena involve very rapid changes in the dynamic and thermal state of the molten particles that depend on many factors, some of them being unknown or not well known. The principle difficulty of the problem arises from the fact that both phenomena occur simultaneously in an extremely short time. Characterizing the deformation behaviour of the droplets during impingement, including flattening and simultaneous solidification, requires the solution to the motion and energy equations to determine the exact behaviour and interaction of the droplets during the process.

The first numerical work in this field was done by Harlow and Shannon [1], who investigated the behaviour of the deformation of a single droplet upon its impingement onto a flat plate and into a pool of the same liquid. They used the "Marker-and-Cell" method to solve the full Navier-Stokes equations in cylindrical coordinates. However, in their calculations, the effects of surface tension and viscosity were completely neglected. Moreover, their study did not include heat transfer. Another numerical effort, which is based on a commercial code called FLOW-3D, has been performed by Trapaga and Szekely [2] to investigate the spreading process of droplets upon impact onto a surface. The equations of fluid flow including continuity equation, classical Navier-Stokes equations and the equation of fluid fraction are solved using the "Marker- and-Cell" method and the implicit-continuous 3-dimensional extension of the SOLA-VOF code. However, only the fluid flow aspects of the problem is considered and the solidification part of the deformation process has not been tackled. Liu et al. [3] have also investigated this