A Critical Assessment of Particle Temperature Distributions During Plasma Spraying: Numerical Studies for YSZ

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Received November 17, 2004; revised April 4, 2005

A three-dimensional computational model is used to simulate the in-flight particle melting behavior during plasma spraying process. The stochastic model is used for the particle size distribution. The particles surface temperature distributions at various spray distances have been presented. The results show that the surface temperature distribution varies with the spray distance. Single peak to double peaks and back to single peak has been observed in the simulations and also in the experiment. The effects of particle size and its distribution and plasma composition on the pattern shift have been investigated. Understanding the pattern shift may enable the design of a good control indicator to determine the particle melting status.

KEY WORDS: Plasma spray; particle temperature; melting.

NOMENCLATURE

$C_p$: specific heat, $J \cdot kg^{-1} \cdot K^{-1}$
$C_D$: drag coefficient
$h$: convective heat transfer coefficient, $W \cdot m^{-2} \cdot K^{-1}$
$k$: thermal conductivity, $W \cdot m^{-1} \cdot K^{-1}$
$L_m$: latent heat of fusion, $J \cdot kg^{-1}$
$L_v$: latent heat of evaporation, $J \cdot kg^{-1}$
$Pr$: Prandtl number
$r$: radial coordinate, $m$
$r_p$: particle radius, $m$
$Re_p$: Reynolds number of particle, $\frac{\rho f |\vec{V} - \vec{V}_p|}{\mu_f}$
$Sh$: Sherwood number
$t$: time, $s$

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53 0272-4324/06/0200-0053 © 2006 Springer Science+Business Media, Inc.
1. INTRODUCTION

Plasma spray has been widely used to produce metallic and ceramic coatings. In this process, powders of coating material are injected into a hot plasma jet, with feeding rate ranging from 2 to 30 g min$^{-1}$. The particles are heated and accelerated in the plasma jet before depositing on the substrate. The interaction of particles with the plasma jet is critical to the coating properties, which, to a large extent, depend on characteristics of particles such as temperature, velocity and melting status at the instant of impact on the substrate. Significant research has been conducted to understand the in-flight particle melting behavior in various thermal spray processes. It has been recognized that the particles melting status is one of the most important factors that affect the splat formation and morphology, subsequent coating microstructure and properties. Thus, accurate and fast identifying particle melting status during experiment will be necessary for design and control of the coating quality.

Direct measurement of particle melting status is difficult in experiments. In practice, an average particles surface temperature has been, instead, measured and used as an indicator to quantify particles melting status. Recent investigations, however, revealed that the average particles surface temperature that is usually measured from on-line particle monitor such as DPV 2000, cannot provide sufficient information on the...