A2-3 SPLAT MORPHOLOGY IN THERMAL SPRAY COATINGS: SIMULATIONS AND EXPERIMENTS

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ABSTRACT

The splat morphology of nickel particles during their impact and solidification onto a stainless steel substrate were studied using both numerical simulations and experiments. In the experiments, the spraying was performed with a dc plasma torch. The torch operated at 17 kW and the argon flow rate was 33 l/min. A nickel powder was sieved to obtain a narrow particle size distribution of +53-60 μm with a mean particle size of 61 μm. The substrate was placed 310 mm from the torch and its temperature was controlled using an electric heater. In-flight particle temperatures were measured at the substrate using a ratio pyrometer. Particle tracking velocimetry was used at the spraying distance to obtain particle impact velocities. The nickel particles were sprayed onto a polished stainless steel substrate with a surface roughness of 0.04 μm. The substrate was heated by an electric heater and its temperature was monitored with a thermocouple. Temperatures of 20°C, 194°C, and 368°C were used for the stainless steel substrate. Splat imaging was performed using a scanning electron microscope (SEM) and the software package OPTIMAS was used for image analysis.

A three-dimensional model of free-surface flows with heat transfer, including solidification, was used to simulate the impact of nickel particles onto the substrate. The impact conditions of the particles were measured experimentally. The nickel particles were 61 μm in diameter and had a temperature of 2050°C (i.e. 600°C above the melting point). The impact velocity was 48 m/s. Fluid flow in impinging particles was modelled using a finite difference solution of the Navier-Stokes equations in a 3D Cartesian co-ordinates assuming laminar, incompressible flow. The flow Reynolds number (assuming radial flow over a flat plate in the particle after impact) was estimated to be at most 10^4, too small to induce turbulence. The surface profile of the deforming particle was defined using the "fractional volume of fluid" scheme. A constant contact angle of 90° was prescribed as a boundary condition. Heat transfer in the particles was modelled by solving the energy equation, assuming densities of liquid and solid to be constant and equal to each other. The enthalpy method was used to solve the energy equation for the liquid and solid phases of the particles at the same time. The free surface of the particle was assumed to be adiabatic: estimates of heat loss by convection from the particle surface to the surrounding gas showed them to be three orders of magnitude lower than that to the substrate. Heat transfer within the substrate was by conduction only. Thermal contact resistance between the splat and substrate were included in the model. Values of contact resistance were provided as an input to the model. Although in principle contact resistance could vary with time and/or position on the interface, we used a constant value in the simulations. In the presence of a solid phase, computations of the velocity field have to account for the presence of a moving, irregularly shaped solidification front on which the relevant boundary conditions have to be applied. We treated the solidified regions of the particles using a modified version of the fixed velocity method.