SPLAT FORMATION IN PLASMA SPRAY COATING PROCESS

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Abstract

Plasma spray coating is a process by which the high temperature of a plasma is employed to melt powders of metallic or non-metallic materials and spray them onto a substrate, forming a dense deposit. The process is commonly used to apply protective coatings on components to shield them from wear, corrosion, and high temperatures. Both direct current plasma (dc), and – to a lesser degree - radio frequency inductively coupled plasma (rf-ICP) is employed as the heat source for melting and accelerating the powders. The process may be at atmospheric pressure or under vacuum.

Plasma coatings are built up by agglomeration of splats formed by the impact, spread, and solidification of individual particles. Figure 2 shows a typical cross-section of dc plasma sprayed nickel coating. The state of particles at the point of impact is dependent on their trajectory and residence time within the plasma. Thus, the particles may be fully or partially melted and few particles may be in solid form. Coating properties such as porosity, adhesion strength, and surface roughness depend on the shape of these splats and how they bond together and to the substrate. The splat shape is dependent on material properties of the powder; impact conditions, e.g., impact velocity and temperature; and substrate conditions, e.g., substrate topology and temperature.

Understanding the dependence of the microstructure of spray coatings on operating conditions of the plasma spray system is of great practical interest. To obtain good quality coatings the spray parameters must be selected carefully, and due to the large variety in process parameters, much trial and error goes into optimizing the process for each specific coating and substrate combinations. A great deal of research is currently devoted to exactly understand how varying spray parameters changes coating properties. Mathematical modelling of the process can play a significant role in reducing the extent of such trial and error procedures.

The paper describes recent developments in modeling formation of plasma spray coatings. Specific attention is paid to the 3-dimensional simulation of droplet impact and solidification under plasma spraying conditions. It is shown that the extent of maximum spread is primarily determined by the Reynolds number and to a lesser degree, by the Weber number. Splashing and break-up is shown to be the result of solidification; fluid instabilities do not play a significant role in this regard (see Figs. 1 & 2). Finally, the effect of solidification on droplet spreading is insignificant when the ratio of Stefan number to Prandtl number is much smaller than unity.

Parallel to the development of the droplet impact model, we are developing a stochastic model of coating formation to predict the microstructure of coatings. Employing a Monte Carlo technique, and by providing information on distributions of
droplet size, temperature, impact speed and location, impact angle, and spray gun movement pattern, we can predict coating thickness, coating surface roughness, and porosity. The splat shapes are directly related to the impact and substrate conditions. Present stochastic model uses simplified disk-shape splats. In future, the splat shapes will be provided from the complete CFD model of the impact.

Figure 1. Final splat shape predicted by the current model; Nickel, 60 µm, 73 m/s, 1600°C, Substrate 25°C.

Figure 2. Interaction of two impacting Nickel Droplets; 60 µm, 48 m/s, 2050°C, Substrate 290°C.

Figure 3. Predicted result for formation of coatings using Monte Carlo approach.