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Numerical and experimental analysis of thermal and mechanical behavior of NiCrBSi coatings during the plasma spray process

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Highlights

1) To simulate the plasma spray process, a 3D multi-layer model with Gaussian profile was developed by Finite Element Method; **2)** The stochastic deposition phenomena were considered for both thermal and mass fluxes in this 3D model; **3)** Compressive stresses were formed during the final cooling due to the mismatch of thermal expansion coefficient between the coating and substrate materials; **4)** Higher cooling efficiency could slightly increase the residual stresses inside the deposited coating.

Abstract

A 3D multi-layer model with Gaussian profile was developed to investigate the thermal and mechanical behaviors of plasma sprayed NiCrBSi coatings during manufacturing. The coating growth was simulated by activating progressively the corresponding elements layer by layer, while the heat contributions of impinging particles and of the plasma jet were assumed as heat fluxes applied on the surface of the substrate or of the previously deposited layers. Thus, the temperature field within the specimen was predicted by considering thermal conduction inside the substrate/coating system, as well as thermal convection and radiation effects on the free surfaces of the sample. The specimen deformation and the stress status were then calculated by considering the transient temperature at each node as a thermal load. The simulated results indicate that quenching stresses dominate final residual stresses in the deposited coating: the final residual stresses are thus tensile within the coating. The simulated temperature variation and final deflection of the specimen agreed well with the corresponding measurements. It was also found that application of a low cooling rate results in lower residual stresses within the deposited coating.

Keywords: Finite element method; Gaussian profile; Plasma spray; NiCrBSi coating; Residual stress; Cooling efficiency.

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