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An Integrated Multiphysics and Multiscale Computational Model for Cold Spray Additive Manufacturing Process

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Cold Spray (CS) is a powder-based additive manufacturing (AM) process using supersonic gas flow to accelerate powder particles to a very high speed before impacting and bonding to the substrate. Compared to laser-based AM processes, CS works with very high volumetric deposition rate and both powder particles and substrate are in the low temperature solid state during coating formation. CS is attracting increasing interest in different industry sectors for applications in rapidly repairing damaged components, building freeform structures, and creating functional coatings.

To comprehensively understand the physics and mechanism of CS process and to predict the coating properties under different process parameters with high fidelity, an integrated multiphysics and multiscale computational model has been developed at IHPC. The model consists of two modular units: (1) a CFD model for gas flow and in-flight particles and (2) a multiscale FEM model for bonding and coating process. The CFD module is developed based on Discrete Phase Method (DPM) to study the characterisation of supersonic gas flows with in-flight powder particles in the CS system. The multiscale FEM model is established at two-scales: mesoscale (particle-scale) for modelling single/few (<100) particle impact, and continuum scale for modelling the coating formed by millions of particles. The mesoscale FEM model is developed based on Eulerian framework, to investigate the strain and stress evolution, temperature history, microstructure formation during high speed impacting of single particle/multiple particles. The continuum scale FEM model is based on micromechanics and homogenization theory, by which thermal and residual stresses of as-deposited coatings are calculated, and the distortion of the coating and substrate are predicted. A novel and accurate indicator for critical bonding velocity is proposed based on the comprehensive study of adiabatic shear instability using the developed mesoscale FEM model.

The present method is employed to guide the CS production process by providing optimal process parameters such as gas pressure, gas pre-heating temperature, and powder mass flow rate. The simulation platform has been successfully validated by comparing with the experimentdal data of CS processes for different material systems.

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