Optimizing Geometric Parameters for Cold Spray Nozzle Design: A Neural Network Approach

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Optimizing cold spray nozzle geometry is challenging due to the lack of direct solution functions, requiring iterative, computationally expensive simulations. This study introduces a novel approach integrating one-dimensional simulations with machine learning to optimize nozzle design efficiently. A Schlieren imaging setup under various spray conditions is employed to validate 3D Computational Fluid Dynamics (CFD) simulations. This validation is then extended to a quasi-one-dimensional compressible flow model in MATLAB, preserving empirical data fidelity. Following model validation, a Monte Carlo approach focuses on the nozzle's diverging section, with a fixed inlet (10 mm), throat (2 mm), and length (150 mm). The diverging section, divided into 50 radial-variable nodes, is analyzed under varying particle sizes (10-50 µm, 0.8 sphericity), inlet temperatures (400-1000 K), and pressures (2-7 MPa). This extensive dataset then trains a neural network capable of forward and inverse problem-solving: deposition efficiency prediction and optimized nozzle geometry generation for given conditions—a solution that bypasses the traditionally prolonged iterative design process. Under fixed spray conditions, the current neural network achieves 96% accuracy in nozzle optimization. Future work will incorporate physics-informed neural networks (PINNs) to optimize nozzle geometry and spray conditions simultaneously, providing a robust framework for cold spray nozzle design.