**High-Speed Imaging-Based Particle Velocimetry for Cold Spray Process**

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The implementation of cold spray (CS) technology in manufacturing and repair necessitates reliable quality control and process monitoring measures. Among the key control parameters, particle size and impact velocity of the feedstock play a crucial role in determining deposition efficiency and coating properties. In this study, high-speed imaging-based particle velocimetry is employed on aluminum and ultra-high temperature ceramics (UHTCs) to : (i) identify the physical factors influencing particle velocity and its variability; (ii) analyze material-dependent differences in particle acceleration and velocity on substrates with varying hardness, and (iii) demonstrate the capabilities of high-speed imaging as a reliable diagnostic tool for assessing the consistency and repeatability of CS systems. The effect of nano and micro-sized particles on the in-flight dynamics and phenomenon of particle impact, deformation and bonding are captured. Using post processing software, the in-flight, deposition and rebound velocities were calculated and corroborated with the energy loss and coefficient of restitution on substrates with varying roughness and hardness.