Microstructural Evolution Quantification of Cold Spray Processed Material Consolidations via Data-Driven Nanomechanical Mapping and Analysis

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In this work, the use of high-throughput nanomechanical property mapping techniques was coupled with statistical analytics, semi-supervised data clustering algorithms, and data-driven microstructural feature extraction via deconvolution methods for direct application to cold spray processed material consolidations. Critical to the successful formulation of (1) a predictive generalizable microstructural evolution model for computationally guided cold spray process parameter optimization and (2) the elucidation of underpinning deformation mechanics associated with supersonic impact-induced structure-processing-properties-performance relations is the ability to quantify the degree of dynamic recrystallization or severe plastic deformation induced crystallographic refinement present within a given cold sprayed material. Accordingly, an appropriate method for achieving such quantification of microstructural evolution for cold spray processed and metallurgical systems is detailed herein. More to the point, massive nanoindentation grid arrays (ranging from 10,000 indents to 100,000 indents) are obtained at a rate of one indent per second. After that, the equally spaced apart indents (and therefore measured properties – for example, hardness, stiffness, and elastic modulus – at each recorded nanoindentation location are collectively processed via K-Means clustering and deconvolution, probability density function distribution formulation and deconvolution, and high-resolution mechanical property mapping algorithms. As a result, precise, accurate, and statistically significant conclusions surrounding the degree of microstructural evolution due to cold spray processing are unveiled. Cold sprayed materials, such as Al 6061, pure Cu, 3xx stainless-steel, pure Ni, Al 7075, pure Ta, among others, are presented to demonstrate and substantiate the reach of the approach detailed and described during this work.