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PROCESS PHYSICS AND VARIABILITY-AWARE MODELING FOR ROBUST BUILDS IN METAL ADDITIVE MANUFACTURING

LANG YUAN[*], TUĞRUL ÖZEL[†] AND CHRISTIAN ROSSMANN[‡]

[*] University of South Carolina
Department of Mechanical Engineering, Columbia, SC, 29201
langyuan@cec.sc.edu and https://research.cec.sc.edu/yuan

[†] Rutgers University–New Brunswick
Department of Industrial and Systems Engineering, Piscataway, NJ 08854
ozel@rutgers.edu and https://ise.rutgers.edu/tugrul-ozel

[‡]NODiVEC, LLC
Irmo, SC, 29063
rossmann@nodivec.com and https://www.nodivec.com/

ABSTRACT

Metal additive manufacturing (AM) processes involve complex thermal, fluid flow, solidification, and mechanical phenomena. Variations in processing conditions, material properties, and thermal histories can lead to unstable melting and solidification, porosity, cracking, residual stresses, and distortion. Although computational modeling of these phenomena has advanced significantly, translating physical understanding into predictive tools for robust process development and reliable manufacturing remains challenging.

This invited session focuses on recent advances in physics-based, computationally efficient, and data-enhanced modeling approaches for predicting process stability, defect formation, and manufacturing outcomes in metal AM. Particular emphasis is placed on connecting fundamental process physics with practical process optimization, defect prevention, and the identification of robust processing windows.

Topics of interest include multiphysics modeling of melt-pool behavior and solidification; prediction of porosity, cracking, and other process-induced defects; thermo-mechanical modeling of residual stresses and distortion; multiscale modeling and efficient computational strategies; physics-informed and hybrid data-driven approaches; uncertainty quantification and process variability; and model calibration and validation through experimental measurements. Contributions addressing the integration of simulation with process monitoring, parameter optimization, and industrial manufacturing workflows are particularly encouraged. By highlighting both fundamental modeling developments and industrial applications, the session seeks to advance simulation-driven process development and improve the consistency, quality, and reliability of metal additively manufactured components.