Simulation for Additive Manufacturing
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How Can Exascale Computational Resources Accelerate Qualification of Additively Manufactured Parts?

John A. Turner[1], James Belak[2], and Lyle Levine[3]

Oak Ridge National Laboratory (ORNL), Oak Ridge, TN, USA
turnerja@ornl.gov, http://www.linkedin.com/in/johnaturner

Lawrence Livermore National Laboratory (LLNL), Livermore, CA, USA
belak1@llnl.gov, https://pls.llnl.gov/people/staff-bios/msd/belak-j

National Institute of Standards and Technology (NIST), Gaithersburg, MD, USA
lyle.levine@nist.gov, https://www.nist.gov/people/lyle-e-levine

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Additive manufacturing (AM), or 3D printing, of metals is transforming the fabrication of parts by reducing the weight of final parts, reducing waste (and hence energy) in the manufacturing process, and dramatically expanding the design space, allowing optimization of shape and topology. However, there remain challenges in qualification of AM parts due to the unique physical phenomena inherent in AM processes. Although the physical processes involved in AM are similar to those of welding, a field with a wealth of experimental, modeling, simulation, and characterization research over the past decades, the failure rate for new AM parts is often as high as 80%. While modeling approaches and simulation tools for welding and similar processes are quite mature, and have been calibrated to the point that they are approaching predictive capability, they are proving to be inadequate for AM processes. We believe this is in part due to the fact that the process-structure-property-performance relationship is typically treated in an uncoupled manner, relying on tabular databases and hence unable to adequately capture the rapid dynamics and non-equilibrium nature of AM processes.

The Exascale Additive Manufacturing Project (ExaAM) is a collaboration between U.S. Dept. of Energy laboratories as part of the Exascale Computing Project[1] (ECP). ECP is a broad program including research efforts in hardware component and system design, system software, system acquisition and deployment, and science application development to deploy a computational ecosystem capable of delivering at least fifty times the performance of today's largest systems.

ExaAM is one of the applications selected for the development and implementation of models that would not be possible on even the largest of today's computational systems. With the prospect of Exascale computing resources in mind, one of the goals of ExaAM is to remove some of the limitations noted above by coupling high-fidelity sub-grid simulations within continuum process simulations to determine microstructure, properties, and hence performance using local conditions.

Figure 1 depicts the relevant physical phenomena in metal additive manufacturing processes, the focus of ExaAM. We briefly describe the overall goals and elements of ECP as well as the technical approach being taken in ExaAM, which involves integrating and extending existing physics

[1] https://exascaleproject.org/

components ([1], [2], [3], [4], [5], [6]), most of which were not developed specifically for AM but which include the relevant high-fidelity physics capabilities. We also discuss plans for verification and validation of this new integrated simulation environment through collaboration with efforts such as AM-Bench, a set of benchmark test problems under development by a team led by NIST [7].

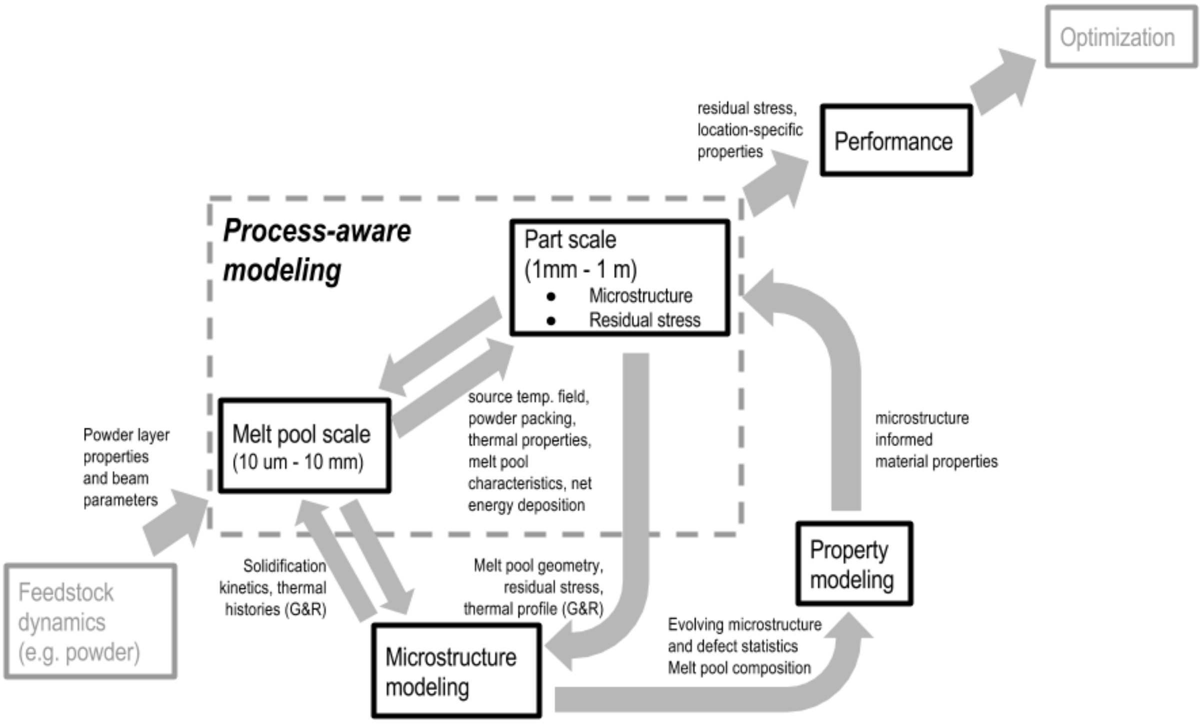

Figure 1: Physical phenomena in metal additive manufacturing processes.

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