MAE *Faculty Candidate* SEMINAR

Process Prediction and Planning of Metal Additive Manufacturing Based on Computational Mechanics of Materials

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ABSTRACT

In the past several years, metal additive manufacturing (AM) has become a revolutionary technology to build three-dimensional complex parts via metallic powders in a layer by layer fashion. Parts built via AM have several advantages over conventional manufacturing including, lower density induced lower energy usage, elimination of multi-step manufacturing of intricated parts, no need for specific tools, reduction in material scrap rate, and many more. Aside from these advantages, there are still some limitations that impede the applicability of the AM such as steep temperature gradient, residual stress, distortion, anisotropy, and heterogeneity in microstructure and mechanical properties.

The available knowledge and technology to-date on the description and prediction of the metal AM process have been fragmented, mostly driven by phenomenological or numerical observations and primarily limited to macroscopic analysis in nature, thus restricting the full capability potential of the AM process. To breakthrough these technology bottlenecks, novel physics-based closed-form analytical thermomechanical models flanked by computational mechanics of materials are proposed to allow rapid, explicit and closed-form solutions of the AM part mechanical attributes including temperature field, thermal stress distribution, and residual stress distribution induced part failure due to crack initiation and growth, and the component microstructural attribute of grain size to be derived as explicit functions of the metal powder starting properties and AM process parameters.

The thermal signature of the AM process is predicted using a transient moving heat source approach. Due to the high-temperature gradient innate in this process, material may experience high thermal stress which often exceeds the yield strength. The thermal stress is obtained from Green's functions of stresses due to the point body load. The modified Johnson-Cook flow stress model is used to predict the yield surface. In this flow stress model, the yield strength parameter is modified to incorporate the effect of grain size using the Hall-Patch equation. The dynamic recrystallization and the resultant grain size are predicted by utilizing the Johnson–Mehl–Avrami–Kolmogorov (JMAK) model. Moreover, a grain refinement model is used to include the effect of the rapid solidification on grain size. Then, as a result of the cyclic heating and cooling and the fact that the material is yielded, the residual stress build-up is precited from incremental plasticity and kinematic hardening behavior of the metal according to the property of volume invariance in plastic deformation in coupling with the equilibrium and compatibility conditions. The predictive modeling results have been experimentally and numerically validated in encouraging agreements.

BIO SKETCH

Elham Mirkoohi is a Ph.D. candidate in the Department of Mechanical Engineering at Georgia Institute of Technology, Atlanta, GA since 2017. She has received her B.Sc. degree from the University of Tehran, Tehran, IR in 2015, and her M.Sc. from Oregon State University, Corvallis, OR in 2017. Elham Mirkoohi's research interests focus on modeling, monitoring, control, and optimization of precision manufacturing, with a special focus on metal machining and additive manufacturing. Her goal is to address the void between mechanical, process mechanics, and materials mechanics knowledge. She has authored more than 25 Journal and Conference papers in top-ranked Journals and Conferences in the field of advanced manufacturing. She also serves as a program committee of several conferences and as a reviewer for more than 27 Journals and Conferences in her field.