COLLEGE OF ENGINEERING
MECHANICAL ENGINEERING
UNIVERSITY OF MICHIGAN

Mechanical Engineering Seminar Series

3D Printing, Synchrotron X-Ray Experiments and Machine Learning

Anthony Rollett
Professor of Materials Science and Engineering,
Faculty Co-Director, Next Manufacturing Center

Carnegie Mellon University

Tuesday, January 19, 2021

4:00 p.m.

ME Seminar Zoom link (QR Code below)

Password 121814

Abstract

3D printing of metals has advanced rapidly in the past decade and is used across a wide range of industry. Although laser powder bed fusion (LPBF) has matured the fastest for metals, other technologies such as binder jet and (robotic) wire feed are making substantial progress. Many aspects of the technology are considered to be well understood in the sense that machines make parts and temperature histories with residual stress can be simulated. Nevertheless, key questions remain open as to how to qualify printers and certify parts, how to control defect structures, which includes surface condition and how to implement more sophisticated control systems. At the microscopic scale, more work is required to quantify, understand and predict defect- and microstructures, which affect properties. Strength, for example, is often at least as good as conventionally processed material whereas defect-sensitive properties such as fatigue are more challenging. Synchrotron-based experiments have been particularly illuminating, e.g., dynamic x-ray radiography (DXR) which provides ultra-high speed imaging of laser melting of metals and their powders. This has, e.g., enabled the keyhole phenomenon to be quantified, which in turn has demonstrated the importance of power density, as opposed to energy density. Under typical LPBF conditions, there is almost always a keyhole present. If the power density is too high, the keyhole is unstable and sheds pores that are trapped by solidification, which turns out to correspond to a sharp boundary in P-V space1† . Energy density, while informative, also fails to capture the crucial boundary between full density and lack-of fusion porosity because it does not take account of melt pool overlap. Synchrotron-based 3D X-ray computed microtomography (µXCT) showed that essentially all metal powders exhibit porosity that partially persists into the printed metal. This explanation is reinforced by evidence both DXR and simulation. The links between porosity and process conditions provide a physics-based approach to defining a process window a given machine which, in turn, suggests a route to qualification by measuring and tracking the location of the process window in power-speed-hatch space for any given powder bed printer. To illustrate the power of machine learning, Computer vision (CV) has successfully classified different microstructures, including powders. Machine learning is providing new insights on correlations between welding parameters, microstructure and material properties in laser hot-wire weld deposits to Ti-6Al-4V. High speed synchrotron x-ray diffraction is providing new information on solidification and phase transformation in, e.g., IN718, Ti-6Al-4V and stainless steel. High Energy (x-ray) Diffraction Microscopy (HEDM) experiments also is also providing data on 3D microstructure and local elastic strain in 3D printed materials such as Ni alloys, Ti-6Al-4V and stainless steel.

Bio

Rollett has been a member of the faculty at Carnegie Mellon University since 1995, including five years as Department Head. He is also the Co-Director of the newly formed NextManufacturing Center on additive manufacturing. Previously, he worked for the University of California at the Los Alamos National Laboratory. There, he was Group Leader of Metallurgy for four years and Deputy Division Director of Materials Science & Technology for one year. He has been a Fellow of ASM since 1996, Fellow of the Institute of Physics (UK) since 2004 and was chosen to be a Fellow of TMS in 2011. He received the Cyril Stanley Smith Award from TMS in 2014, was elected as Member of Honor by the French Metallurgical Society in 2015 and became the US Steel Professor of Metallurgical Engineering and Materials Science in 2017. He received the Cyril Stanley Smith Award from the International Conference on Recrystallization and Grain Growth in 2019 and also the International Francqui Professor for 2020-2021, from the Francqui Foundation, Belgium. The focus of my research is on additive manufacturing, the measurement and prediction of microstructural evolution, the relationship between microstructure and properties, with a particular emphasis on three-dimensional effects, texture & anisotropy and the use of synchrotron x-rays.