Extrusion-Based Additive Manufacturing of Metal Materials through Theoretical, Computational, and Experimental Study

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Abstract

Additive manufacturing (AM) has been widely adopted to build metal components for industrial applications. For building high-strength metals like steels, nickel alloys, and titanium, prevalent AM technologies include powder-bed fusion (PBF) and directed energy deposition (DED), both of which utilize high energy input to melt and solidify the material on a building platform. In recent decades, material extrusion-based sintering-assisted approach has emerged as an alternative because it provides significantly less cost but also reasonable strength. It also favors large-scale builds due to the high manufacturing speed. A variety of metal materials/alloys have been fabricated through material extrusion-based AM, such as iron, steels, titanium, nickel, copper, and tungsten.

The overarching goal of my dissertation is to advance the fundamental understanding of the process-structure-property (PSP) relationship underlying the extrusion-based AM process and to investigate additional possibilities for its application in industrial contexts. The objective of this study can be decomposed into four tasks: 1) Quantify the effect of process on the microstructure evolution through numerical simulation; 2) Predict the shrinkage and deformation of 316L stainless steel parts built by extrusion-based AM; 3) Discover the formability and mechanical performance of lattice structures built by extrusion-based AM; 4) Reveal the feasibility and interfacial bonding for steel-Inconel bi-metal structure manufactured through extrusion-based AM.

This dissertation provides a comprehensive and in-depth analysis of the extrusion-based sintering-assisted AM process in the aspects including process modeling, structure evolution, and performance evaluation. The scientific insights generated from this dissertation could spur more rigorous research in extrusion-based additive manufacturing processes, advance the field of metal additive manufacturing, and foster broader adoption of this processes across various industrial applications.