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Solid-State Additive Manufacturing via Additive Friction Stir Deposition: Process-Microstructure Linkages

Author(s): Joey Griffiths[1], David Garcia[1], Jie Song[2], Vijay K. Vasudevan[2], Matthew A. Steiner[2], Wenjiun Cai[1], Yi Han[1], Yunhui Zhu[1], Hang Yu[1]

[1]Virginia Tech **[2]University of Cincinnati**

Abstract

Among metal additive manufacturing technologies, additive frictions stir deposition stands out for its ability to create freeform and fully-sense structures without the melting and solidification seen in beam-based additive processes. Here, we employ a comparative approach to investigate the process-microstructure linkages in additive friction stir deposition, utilizing two materials with distinct thermomechanical behavior – an Al-Mg-Si alloy and Cu – both of which are difficult to print via beam-based additive technologies. Across the range of process variables tested in this work, Al-Mg-Si exhibits a relatively homogeneous microstructure with extensive subgrain formation and a strong shear texture. In contrast, the deposited Cu is characterized by a heterogeneous microstructure with varied grain sizes and local misorientations, along with a weaker shear texture. We show evidence that the microstructure in Al-Mg-Si primarily evolves by continuous dynamic recrystallization, including geometric dynamic recrystallization and progressive lattice rotation. The more heterogeneous microstructure of Cu results from the discontinuous recrystallization processes during deposition as well as during cooling. In Al-Mg-Si, the recrystallization progresses with increasing strain, which is found to correlate with the ratio between the tool rotation rate Ω and travel velocity V. Meanwhile, the peak temperature influences the recrystallization rate owing to precipitate evolution. In Cu, the microstructure evolution is found to be less dependent on Ω, instead varying greater with changes to V. The distinct process-microstructure linkages and underlying mechanisms between Al-Mg-Si and Cu are attributed to their differences in intrinsic material properties, interactions with the rotating tool head, and restoration phenomena responsible for microstructure evolution. In an effort to accelerate this type of process-microstructure characterization for more process variables, materials, and even process methods, a new

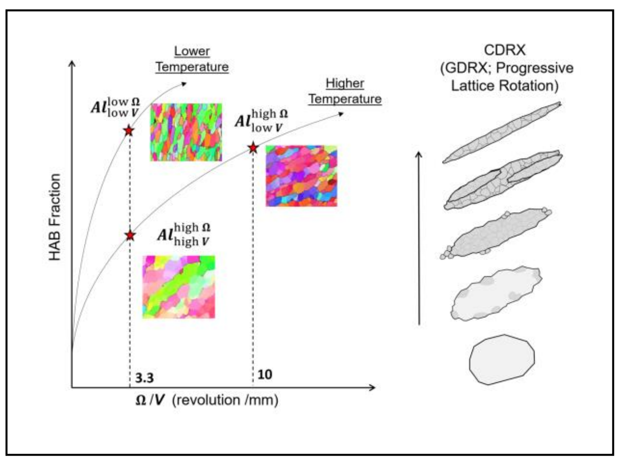

Figure 1. Processing influences on the microstructure evolution during AFSD of Al-Mg-Si, primarily through CDRX phenomena.

method utilizing image based deep learning was developed. The goals of which are method for microstructure qualification, analysis, and prediction.

Biography

Joey is a PhD student at Virginia Tech, he received his Bachelor's degree in Material's Science and Engineering from Virginia Tech in 2017, and began his graduate studies the same year, advised by Dr. Hang Yu. He plans to graduate in the Spring of 2021. His research has focused largely on the additive manufacturing process, Additive Friction Stir Deposition (AFSD), which was originally invented by Virginia Tech scientists and is currently commercialized by the MELD Manufacturing Corporation. His work with AFSD is centered on in process evolution phenomena including phase transformation, phase evolution (mechanical-mixing) and dynamic microstructure evolution (largely through recrystallization). Additionally, he is involved in projects focused on harnessing these phenomena to optimize the performance of material deposited via AFSD. Joey has multiple publications on the above topics and has presented at the MS&T and TMS conferences. A full list of publications can be found at (https://www.researchgate.net/profile/R_Griffiths).