6 November 2020

Complex Three-Dimensional Material Flow during Additive Friction Stir Deposition of Dissimilar Aluminum Alloys

Mackenzie E.J. Perry[1, 2], R. Joey Griffiths[1], Hunter A. Rauch, Jennifer M. Sietins[2], David Garcia[1], Yunhui Zhu[3], Hang Z. Yu[1]

[1] Department of Materials Science and Engineering, Virginia Tech, Blacksburg, VA 24061, USA
[2] CCDC Army Research Laboratory, Aberdeen Proving Ground, Aberdeen, MD 21005, USA
[3] Department of Electrical and Computer Engineering, Virginia Tech, Blacksburg, VA 24061, USA

Abstract

Additive friction stir deposition is an emerging solid-state additive process that is renowned for good interface adhesion and a low degree of mechanical anisotropy, which has been postulated to originate from the material deformation and flow phenomena near the interface. However, a fundamental understanding of the material flow characteristics still remains elusive.

Here, we present a quantitative investigation of three-dimensional material flow in additive friction stir deposition via morphological and microstructural studies, wherein the morphology is characterized using X-ray computed tomography and the material deformation history is explored by electron backscatter diffraction. Depositing a *homogeneous* Al 2024 feed rod onto an Al 6061 substrate allows us to investigate the three-dimensional interfacial morphology formed during additive friction stir deposition. We also investigate the material flow within the deposition zone by depositing *hybrid* feed rods consisting of Al 2024 (tracer core) and Al 6061 (shell) onto Al 6061 substrate.

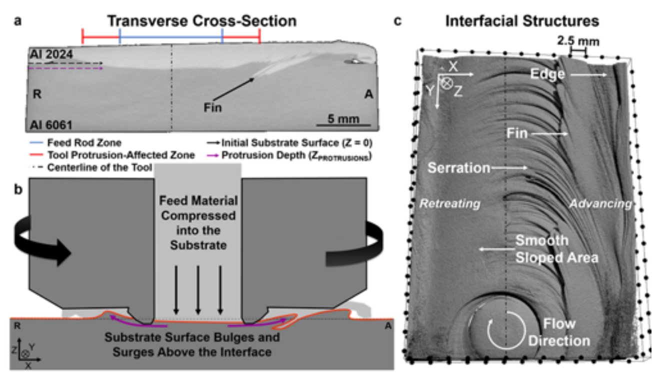

Figure 1. X-ray computed tomography results for AA 2024 deposited onto AA 6061 via AFSD. a) A representative transverse cross-section of the deposit and substrate highlighting the bowl-shaped interface and macroscopic mixing, b) Schematic of the key interfacial material flow processes, c) Underside of the deposited AA 2024 material with the substrate material removed and a few salient features highlighted.

Based on dissimilar aluminum deposition, we find significant macroscopic material mixing across the initial substrate surface. The deposited material penetrates below the initial substrate surface in the feed rod zone and the substrate surges above the initial substrate surface in the tool protrusion-affected zone. Interestingly, this non-flat interface is asymmetric along the deposition width. Complex three-dimensional structures, like fin and serration structures, form on the advancing side, whereas the interface manifests as a smooth sloped surface on the retreating side. Microstructure mapping reveals a uniform thermomechanical history for the deposited material, which develops a homogeneous, almost fully recrystallized microstructure. The substrate surface develops partially recrystallized microstructures that are location-dependent. During the deposition of the hybrid feed rods, the initial cylinder shape of the tracer material is expanded out to long, thin ribbons after deposition. This initial study lays the groundwork for strain and strain rate estimation, microstructure evolution, and more process control in additive friction stir deposition.

Biography

Mackenzie Perry is a Ph.D. candidate (expected graduation Spring 2021) in Dr. Hang Yu's research group. Following her graduation from Virginia Tech with a bachelor of science in Materials Science and Engineering in 2017, she received the NSF Graduate Research Fellowship Program (GRFP) Fellowship and started her graduate research. After finishing all of her graduate courses in Blacksburg, Mackenzie has been conducting her research at the Army Research Laboratory (CCDC ARL) in Aberdeen, Maryland. Her research focuses on material flow and microstructure evolution during Additive Friction Stir Deposition (AFSD). She was a co-author on two of the first papers related to AFSD (https://yu.mse.vt.edu/Publications.html) and she recently published a first-author paper entitled "Morphological and microstructural investigation of the non-planar interface formed in solid-state metal additive manufacturing by additive friction stir deposition". This past November, she won "Best Experimental Approach" in the NSF-Student Research Poster Competition at IMECE 2019 in Salt Lake City.