Laser ultrasonic process monitoring during directed energy deposition additive manufacturing

Chaitanya Bakre[1], Gerald Boddie[1], Cory Jamieson[2], Baily Thomas[2], Abdalla Nassar[2], Edward Reutzel[2], Cliff Lissenden[1]

[1]Engineering Science and Mechanics, Penn State, USA, [1]CIMP-3D, Penn State Applied Research Lab, USA

Increasing adoption of additive manufacturing (AM) processes in various industrial sectors and high market competitiveness couple with the need to produce high-quality parts and increase affordability. In-situ process monitoring of the AM part itself offers the potential to enhance product quality, detect defects early (i.e., during processing), and provide closed-loop feedback control. While most of the current in-situ methods are vision-based, laser ultrasonics (LU) can interrogate the evolving surface of the part during the layer-by-layer process. The final result is a volumetric interrogation of defects and inference about the material's microstructure, which dictates the strength of the part. Here, we present a fully noncontact laser ultrasonic test setup to provide layer-by-layer monitoring during directed energy deposition AM processing. A Q-switched Nd:YAG laser irradiates the surface of the AM part and generates a narrowband Rayleigh wave. The center frequency and its bandwidth are dictated by the illumination pattern, which is an array of lines. A fiber-delivered adaptive laser interferometer receives the Rayleigh waves as well as near-surface waves. The current state of development is alternating material deposition and ultrasonic interrogation. We describe the integration of the laser ultrasonic system into a directed energy deposition AM chamber, provide results from titanium alloy builds, and discuss the effect of in-situ surface roughness on the results.