Automated Multi-Modal In-Process Non-Destructive Evaluation of Wire + Arc Additive Manufacturing

Abstract

High deposition rates for manufacturing of large components through Wire + Arc Additive Manufacturing (WAAM) has given the technology a distinct edge over other AM techniques. Given their target markets in defense, aerospace and nuclear industries, high Non-Destructive Evaluation (NDE) reliability is critical for the components. Therefore, in this work, two NDE modalities were robotically deployed during the manufacturing process at high temperatures to ensure the component's integrity as it is being built. This approach for In-process automated inspection of WAAM, deployed after deposition of every few layers, provides the opportunity for the process intervention as the defects can be detected early in the process reducing the time/cost associated to part scrappage. This work presents a proof of the concept of in-process NDE of WAAM using two different sensor modalities: a) a high temperature phased array Ultrasound Testing (UT) roller-probe, and b) a high-temperature flexible Eddy Currents (EC) testing array. The automation cell is composed of two robots dedicated to the WAAM deposition process and the NDE sensor delivery on the WAAM. A titanium WAAM component with a straight geometry was deposited using the plasmaarc process and tungsten tube and ball reflectors of varying sizes/orientations were intentionally embedded in between different WAAM layers to assess the performance of each of the NDE modalities in-process. Full external control of the sensor enabled adaptive motion control for the NDE robot and the integrated UT and EC array controllers and probes were achieved through a central program developed in the LabVIEW platform. Moreover, realtime robot motion corrections, driven by the ForceTorque sensor feedback, were established to adjust the contact force and orientation of the sensors to the component surface during the scan. The C-scans were produced live from both UT and EC arrays demonstrating the successful detection of embedded tungsten defects with high SNRs.

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