Title: Microstructure, Residual Stress, and Mechanical Behavior of SS-316L Manufactured via Laser-wire Direct Energy Deposition

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Abstract:

Additive Manufacturing (AM) is revolutionizing the production process with its efficiency and sustainability. By allowing for small-scale, near-net-shape (i.e. minimal machining and waste), and localized production, AM reduces the carbon footprint of both manufacturing and transportation, making it an environmentally friendly solution. With its ability to quickly produce complex or obsolete replacement parts, AM helps minimize downtime and maintenance costs, particularly for high-value components like those used in nuclear reactors. Wire-based AM techniques, such as Laser-wire Direct Energy Deposition (LW-DED), have a higher deposition rate and lower cost than powder bed processes. These qualities make wire-based AM particularly well-suited for manufacturing large-scale components for high-value applications. Despite the advantages of LW-DED, the residual stress distribution in manufactured components (especially large components) can impact their structural performance. To gain a better understanding of this phenomenon, components made from SS-316L wire using LW-DED were studied with varying build geometries and interlayer temperatures. Spatial resolution of residual stress was achieved through the use of neutron diffraction and further complemented by correlating the results with measurements obtained using X-ray diffraction, thereby providing a comprehensive understanding of the residual stress distribution throughout the specimens. The results were analyzed in relation to the microstructure and mechanical behavior of the printed components, providing insight into the scalability and industrial usage of wire-based AM processes. The findings of the study showed that the highest levels of residual stress were observed near the free surfaces, while no significant stress concentrations were present in the transition from thick to thin sections. Further analysis showed that the presence of large grains or clusters of grains was linked to residual stress, which can be visualized through qualitative SEM imaging.