

# **Low-Cost, Enclosed Wire-Arc Additive Manufacturing Platform with Unified G-Code Control**

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## **Abstract**

Additive manufacturing (AM) has, since its emergence, provided a flexible alternative to traditional manufacturing processes, such as casting and CNC machining, by enabling the fabrication of complex geometries. However, powder-based AM processes (e.g., Powder Bed Fusion, PBF) often suffer from low deposition rates and notable material waste. Wire-arc additive manufacturing (WAAM), which leverages conventional welding techniques, offers a more sustainable approach with higher deposition rates and reduced feedstock waste. Yet the high cost of commercial WAAM systems continues to limit broader adoption of this technology. This project aims to design and fabricate a WAAM system that is low-cost, versatile, and safe. Using four stepper motors, the XYZ motion and wire feed are coordinated via a simple microcontroller-based control kit. A MIG welding machine is integrated and actuated by the same controller, enabling end-to-end operation from a single G-code stream. Safety measures include an emergency stop for full-system shut off and a fully enclosed cell with protective viewing panels to shield users from debris, sparks, and UV/IR radiation generated during operation. The resulting WAAM platform can print complex metal features and components while reducing material waste at a fraction of the cost of commercial systems. Beyond new-build parts, the platform is intended to support repair and remanufacturing workflows via controlled bead deposition and feature build-ups. In Phase Two, we will incorporate in-situ monitoring and machine-learning-assisted closed-loop control to automatically detect process anomalies and correct them in real-time, laying the groundwork for an open-source, extensible WAAM ecosystem.

## **Keywords**

Metal additive manufacturing; Wire-arc additive manufacturing (WAAM); Cost-effective manufacturing; Repair and remanufacturing; Industrial applications.

## **Biographies**

**Husam Alrehaili** is the Head of the Department of Mechanical Engineering at the University of Tabuk, Saudi Arabia. He earned his Ph.D. in Mechanical Engineering from Wayne State University (Detroit, USA) in 2024, an M.Sc. in 2018, and a B.Sc. from King Abdulaziz University in 2012. His professional background combines industry and academia, as he worked with Saudi Aramco's Berri Gas Plant in mechanical engineering roles and completed training with SABIC (Hadeed) and the Saudi Electricity Company before transitioning to university service. His research interests center on additive manufacturing and alloy development, including laser metal deposition, high-throughput alloy screening, and Ni/Co/Al-based systems; he has developed toolpaths for robotic deposition, designed new alloys, and led experimental campaigns in microstructure-property optimization. In teaching, he has contributed to design and manufacturing across various areas, including senior capstone projects, design of machine elements,

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