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Optimizing Process Parameters for VANCAR-O Deposition in Wire Arc Additive Manufacturing

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ABSTRACT

Wire Arc Additive Manufacturing (WAAM) is rapidly gaining prominence in aerospace, defense, and manufacturing industries due to its high deposition rates, cost efficiency, and suitability for fabricating large-scale metallic components. Integration of robotic manipulators in the WAAM process provides enhanced flexibility and precision while producing complex geometries. However, achieving uniform deposition with optimal bead characteristics remains a critical challenge. This study focuses on optimizing the parameters for VANCAR-O wire deposition using Gas Metal Arc Welding (GMAW) in a robotic WAAM setup. VANCAR-O is a tubular open arc wire which results in a deposit containing vanadium and tungsten carbide. Due to its material characteristics, including high hardness and superior thermal and electrical conductivity, VANCAR-O presents challenges in deposition processes. To systematically analyze and improve deposition quality, the Response Surface Methodology (RSM) was employed, using a Central Composite Design (CCD) to develop the Design of Experiments (DoE). The optimization criteria aimed to enhance deposition uniformity by maximizing the deposition efficiency while minimizing defects such as humping and excessive bead curvature. Experimental trials were conducted using a FANUC robotic arm equipped with an ESAB welding torch, evaluating the effects of torch travel speed, current, and wire feed rate on the VANCAR-O deposition bead. A shielding gas mixture of CO_2 and Argon was used, while voltage was maintained at a constant level. The statistical approach provided a predictive model for optimizing deposition characteristics and achieving process stability. The optimized parameters resulted in improved bead geometry with reduced surface irregularities and better layer stacking. This study establishes a robust framework for controlling VANCAR deposition in WAAM, ensuring improved repeatability and structural performance for industrial applications requiring high-strength and wear-resistant components.