STEEL ALLOYS IN WIRE ARC ADDITIVE MANUFACTURING: CHALLENGES, OPPORTUNITIES, AND APPLICATIONS

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ABSTRACT

Arc-based Additive Manufacturing (WAAM) is emerging as a cost-effective and efficient method for fabricating large-scale metal components like steel-based alloys. This study explores the use of WAAM in producing mild, stainless, and duplex steels by exploring their advantages and fabrication challenges. Mild steel has good weldability and low cost but suffers from thermal distortion and geometric inaccuracies. Stainless steel provides good corrosion resistance but is prone to anisotropy and microstructural inconsistency. Duplex steel has both high strength and corrosion resistance, yet it demands precise thermal control to maintain phase balance and avoid cracking. The review explores AI-driven control strategies for defect reduction and performance enhancement. This work aims to guide organisational developments and enhance industrial adoption of WAAM for steel-based alloy components in marine, energy, and structural sectors.

Keywords: *Steel Based Alloys; WAAM; Process Optimization; Structural Applications.*

1. INTRODUCTION

Metal Additive Manufacturing (MAM) has transformed advanced manufacturing by enabling the layer-by-layer fabrication of complex geometric parts directly from CAD files. Metal-AM has offered benefits such as design flexibility, material efficiency, and reduced lead time, specifically for high-performance applications like aerospace, energy, and marine industries [1]. Steel alloys (mild, stainless, and duplex steel) are widely used due to their strength, corrosion resistance, and cost-effectiveness in all types of structures [2]. Traditional manufacturing methods often result in high material waste and geometric limitations, prompting interest in metal AM for structural applications. Among all metal AM technologies, arc-based AM has gained attention for its ability to produce large, near-net-shape components using arc welding processes like Gas Metal Arc Welding (GMAW), Cold Metal Transfer (CMT), and Plasma Arc Welding (PAW) [1]. Except for high deposition rates and low operational costs, it faces challenges like microstructural and mechanical variability and poor surface finish. These issues are especially critical when working with compositionally complex steels like duplex alloys [3]. Therefore, this review provides a comparative analysis of WAAM-fabricated mild, stainless, and duplex steels, focusing on their process responses, behaviour, and mechanical performance. It also highlights current research gaps and emerging optimisation strategies to support large-scale industrial applications. The types of AM and all application of mild, stainless, duplexsteel are presented in Fig. 1 (a) and (b).