Comparison of Fixed Dwell Time and Interpass Temperature-Controlled Strategies for Thin-Walled WAAM-CMT ER70S-6 Depositions

Dylan Browne[1,*], Edward Archer [2], Cormac McGarrigle [1] and Ryan Harkin [1].
[1] School of Computing, Engineering and Intelligent Systems, Ulster University, Northern Ireland, UK.
[2] School of Engineering, Ulster University, Northern Ireland, UK.
* Correspondence: browne-d9@ulster.ac.uk

ABSTRACT

Wire Arc Additive Manufacturing (WAAM) enables the fabrication of large-scale metallic components with a high deposition rate (2-3 kg/hr) [1]. However, this additive process can be susceptible to thermal accumulation which can negatively affect geometrical and mechanical characteristics. This study investigates the influence of two temperature control strategies: fixed dwell time and interpass temperature control (200 °C threshold), during the development of ER70S-6 thin-walled structures using the WAAM-Cold Metal Transfer (CMT) process. Mechanical and microstructural analysis were conducted. Comparatively, the interpass temperature control strategy increased the mean ultimate tensile strength by 13.42% against fixed dwell-time, while producing an improved homogenous microstructure and therefore reducing the variation within the deposition. These findings demonstrate the importance of thermal management in enhancing WAAM component quality and consistency.

KEYWORDS: Wire Arc Additive Manufacturing (WAAM); ER70S-6; Temperature Control

1. INTRODUCTION

Temperature control is critical to control thermal accumulation, microstructural development, and geometric stability of as-built depositions [2]. There are two main temperature control methods, fixed time and interpass temperature control. Liberini et al. [3] displays the use of fixed dwell time (60s) as a measure to alleviate thermal accumulation. Costa et al. [4] has highlighted that for ER70S-6, maintaining an interpass temperature of approximately 200°C provides a balanced deposition, strong fusion between layers, stable bead geometry and a more uniform microstructure through the build.

2. MATERIALS AND METHODS

Single-track thin-walled depositions consisting of 60 layers were manufactured using a KUKA KR16-HW robotic system equipped with a Fronius TPS400i CMT power source. Depositions were produced using ER70S-6 wire with the following process parameters: wire feed speed; 3.50 m/min, travel speed, 0.75 m/min; voltage, 0.75 V; current; 129 A. Two processing strategies were investigated.
Fixed Dwell Time (FDT): 60 second fixed dwell time between layers (based off ER70S-6 cooling rate using selected parameters) and Interpass Temperature Control (ITC): subsequent layer temperature of 200°C to initiate the deposition of next layer.

Mechanical behaviours of tensile coupons extracted at 0°, 45°, and 90° orientations relative to the substrate were analysed using an EWN-W100K Universal Test Machine, equipped with a 20 kN load cell in accordance with ASTM A370 [5]. Three-dimensional (3D) microhardness mapping (recorded using Future-tech FM-800 Microhardness Tester), surface waviness, effective wall thickness, grain size and microstructural analysis were also conducted (Using Leica DMi8 for micrographs and image processing).

3. RESULTS

The FDT samples displayed orientation-dependent behaviour, with the highest Ultimate Tensile Strength (UTS) recorded at 0° (574.21 ±48.71 MPa) and the lowest at 90° (480.76 ±66.37 MPa) as shown in Table 1. ITC samples demonstrated improved consistency and mechanical performance. Maximum UTS reached 651.28 ±67.79 MPa at 90°. Mean hardness increased from 153.02 ±8.87 HV in the FDT condition to 168.84 ±4.22 HV under ITC. Grain size was also refined from 52.14 ±76.59 μm² in the FDT to 25.38 ±16.46 μm² in ITC (Table 1).

© The Author(s) 2026
D. Nikam et al. (eds.), *Proceedings of the Global Symposium on Adaptive Manufacturing (GSAM 2026)*,
Advances in Engineering Research 308,
https://doi.org/10.2991/978-94-6239-813-9_4

Furthermore, ITC reduced the manufacturing time from 83.8 min to 72.7 min while reducing surface waviness from 0.7 mm to 0.4 mm and improving effective wall thickness by 0.3 mm.

Table 1 - Mechanical and geometrical properties of fixed dwell time and interpass temperature control depositions

	Ultimate Tensile Strength (MPa)			Mean Vickers Hardness (HV)	Mean Grain Size (μm²)	Max Surface Waviness (mm)	Effective Wall Thickness (mm)	Total Deposition Time (mins)
	0°	45°	90°					
FDT	547.21	502.55	480.76	153.02	52.14	0.7	2.9	83.8
	±48.71	±97.05	±66.37	±8.87	±76.59	±0.2	±0.2	
ITC	621.71	595.59	651.28	168.84	25.38	0.4	3.2	72.7
	±9.39	±90.07	±67.79	±4.22	±16.46	±0.1	±0.1	

4. DISCUSSION

The results demonstrate a strong relationship between thermal history, microstructure, and mechanical performance. Fixed dwell deposition produced larger grain structures and greater anisotropy due to thermal accumulation during multilayer fabrication. Interpass temperature control provided the most balanced solution by regulating thermal accumulation throughout the build process. Maintaining the ambient temperature at 200 °C provided relatively consistent cooling conditions, promoting grain refinement and a more homogeneous microstructure (Fig. 1), which contributed to improved hardness distribution, tensile properties, and reduced anisotropy. The simultaneous reduction in manufacturing time further highlights its industrial potential for WAAM applications.

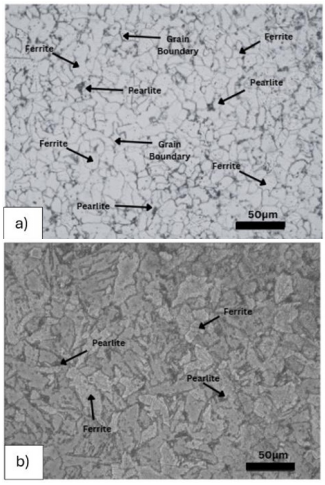


Figure 1 - Micrograph of ER70S-6 depositions manufactured using a) FDT b) ITC

5. CONCLUSIONS

This study demonstrates that deposition strategy significantly influences the mechanical and metallurgical performance of ER70S-6 WAAM-CMT multilayer thin-wall structures.

- FDT depositions exhibited a more anisotropic tensile behaviour.
- ITC depositions improved tensile strength (13.61%), hardness distribution (10.34%), and microstructural homogeneity.
- Effective wall thickness increased from 2.9 mm (FDT) to 3.2 mm (ITC) and decreased surface waviness from 0.7 mm (FDT) to 0.4 mm (ITC)
- Grain size was reduced by approximately 51% compared with the FDT condition.
- Manufacturing time was reduced by 11.1 minutes compared with FDT deposition.

REFERENCES

[1] Y. Li, C. Su, and J. Zhu, "Comprehensive review of wire arc additive manufacturing: Hardware system, physical process, monitoring, property characterization, application and future prospects," *Results in Engineering*, vol. 13, p. 100330, Mar. 2022, doi: 10.1016/J.RINENG.2021.100330.

[2] S. A. Rizvi and W. Alib, "Welding defects, Causes and their Remedies: A Review," *Teknomekanik*, vol. 2, no. 2, pp. 39–47, Dec. 2019, doi: 10.24036/TM.V2I2.3272.

[3] M. Liberini *et al.*, "Selection of Optimal Process Parameters for Wire Arc Additive Manufacturing," *Procedia CIRP*, vol. 62, pp. 470–474, Jan. 2017, doi: 10.1016/J.PROCIR.2016.06.124.

[4] A. L. S. da Costa, R. L. de Paiva, D. de Oliveira, and M. Ziberov, "Influence of Interlayer Temperature and Deposition Method on the Wall Geometry and Vickers Microhardness Profile of ER70S-6 Parts Manufactured by Additive Manufacturing Using CMT," *Journal of Manufacturing and Materials Processing*, vol. 9, no. 3, Mar. 2025, doi: 10.3390/jmmp9030093.

[5]"ASTM International, *ASTM A370-26: Standard Test Methods and Definitions for Mechanical Testing of Steel Products*. West Conshohocken, PA, USA: ASTM International, 2026.".

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (http://creativecommons.org/licenses/by-nc/4.0/), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

