Abstract of the Thesis

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Title of the Thesis: **Investigation of process parameters on the quality of aluminium components manufactured through Wire Arc Additive Manufacturing (WAAM)**

Abstract

Wire arc additive manufacturing (WAAM) of aluminium is limited by heat accumulation, which as layers build up raises the interpass temperature and degrades geometry, grain structure and mechanical isotropy. Active cooling is the accepted remedy, but reported methods use different rigs, feedstocks and protocols, so their merits cannot be compared directly. This work evaluates seven interpass cooling strategies under identical GMAW-WAAM conditions on ER5356 thin wall structures: natural cooling (NC), passive cooling (PC), active immersion cooling at two layer edge to water distances (A20, A10), the novel Tandem Immersion Active Cooling strategy (TIAC), its bidirectional variant (TIAC-BD) and cryogenic liquid nitrogen cooling (LN_2). Each was characterised for thermal history (Heat Accumulation Index), geometry, tensile, impact and hardness response, chemistry, microstructure, phase and texture, and fracture behaviour. The principal contribution is the TIAC architecture, which combines substrate immersion with a synchronised inter-layer impingement jet and cuts the HAI by 62.3% relative to NC (145.9 to 55.0 °C) at 2.9 times the immersion only heat input, outperforming every single mode strategy while building taller layers. TIAC-BD gives the lowest surface waviness (0.78 mm), and LN_2 the finest grain (42.5 µm) but the highest substrate HAI (170.3 °C). A multi criteria matrix identifies TIAC as optimal, supported by a process structure property linkage. TIAC offers the best balance of quality, productivity and implementability for structural thin wall aluminium components, using only tap water and a

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locally fabricable tank, pump and nozzle assembly deployable on an existing WAAM cell at modest cost.

This PhD Thesis would be useful for manufacturers producing thin wall aluminium components by wire arc additive manufacturing (WAAM), offering a low cost, locally fabricable active cooling system for aerospace, automotive and structural use. It gives process engineers evidence-based guidance for selecting a cooling method and parameters for a target quality and productivity, and supports wider industrial adoption of WAAM aluminium.

List of Publication(s):

1) Patel, D. B., & Pujara, A. A. (2026). Influence of active cooling on microstructure and mechanical properties of wire arc additively manufactured 5356 aluminium alloy. Engineering Research Express. volume 8, issue 2, pp 025505, https://doi.org/10.1088/2631-8695/AE35E4

2) Patel, D. B., Pujara, A. A., (2025). A review of various heat mitigation techniques in Aluminium alloy fabricated by wire arc additive manufacturing. International Journal of Advanced Research in Science, Engineering and Technology, volume 12, issue 3, pp 23068. https://www.ijarset.com/upload/2025/march/18-akashpujara-17.pdf