Microstructure and Deposition Integrity in Multi-Pass COBOT-Assisted WAAM: An Experimental Investigation

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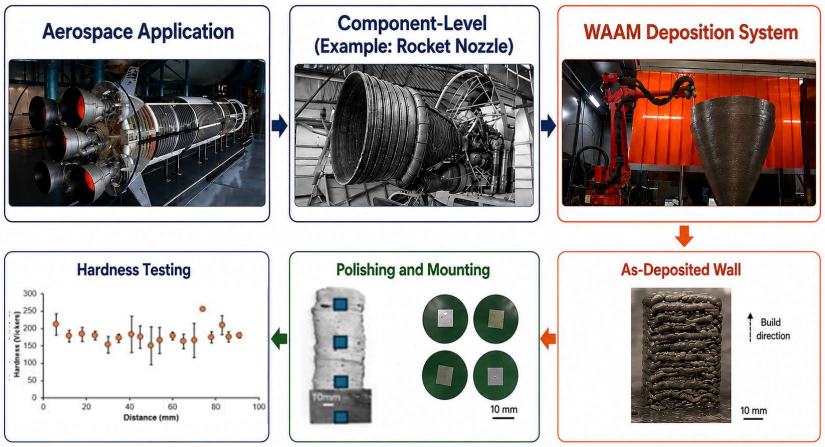

Problem Statement and Objective

- In multi-pass and multi-layer deposition in WAAM, controlling the evolution of microstructure and maintaining consistent geometry becomes increasingly challenging due to heat accumulation and inter-pass reheating. These thermal effects influence grain morphology, fusion integrity, and the occurrence of defects
- The objective of this study is to consider how multiple weld passes enabled through a collaborative robot (COBOT) affect the deposition uniformity in WAAM by measuring the hardness and microstructure through optical microscopy.

Figure 1: A schematic representation of the experimental procedure of multipass deposition by using a collaborative robot-integrated wire arc additive manufacturing of ER308 steel on a stainless steel 304 substrate.

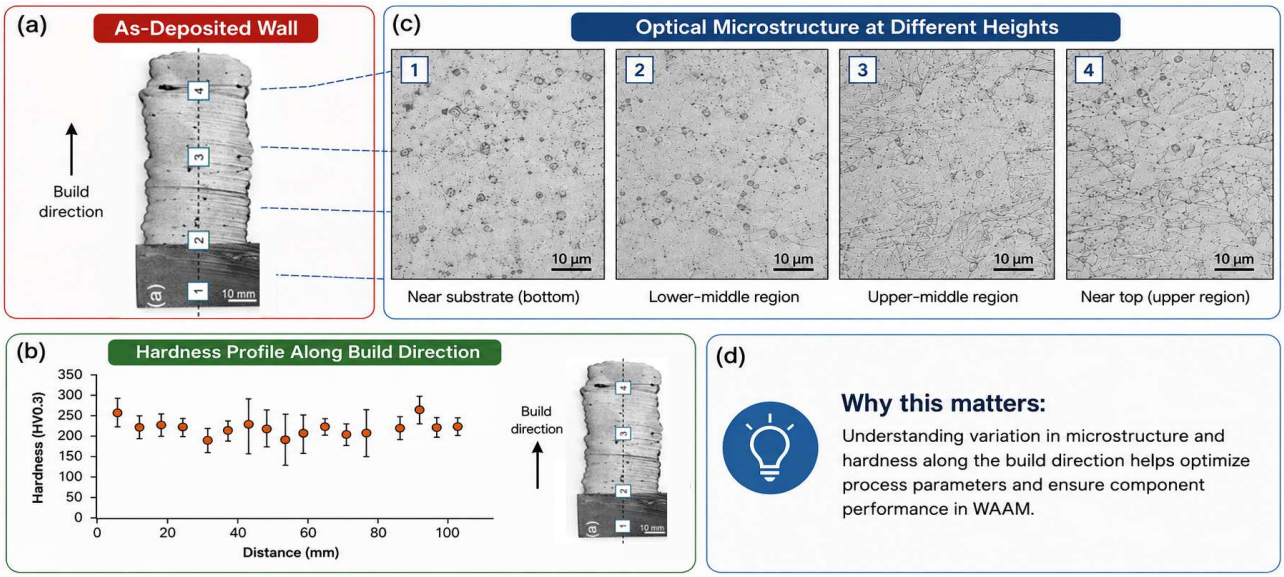

Figure 2: (a) Cross section of multipass deposition through COBOT-integrated WAAM, (b) hardness vs distance for different along the printing direction (c) microstructure of WAAM 308 L stainless steel characterized by optical microscopy

Results

- Hatch spacing significantly affected overlap and fusion consistency.
- Grain morphology transitioned from columnar to equiaxed as layer number increased, due to inter-pass reheating and decreased thermal gradient.
- Inadequate inter-pass delay led to lack-of-fusion defects at the bead interface.
- COBOT guidance ensured consistent torch positioning and oscillation pattern, enabling repeatable thermal conditions.

Methods

- A series of 10 passes, multi-pass welds were deposited for 20 layers using SS 308L as a feedstock in a COBOT-guided WAAM setup on a steel substrate.
- After deposition, samples were sectioned, mounted, polished, and etched to reveal grain morphology.
- Microstructural analyses were performed using optical microscopy.

Discussion

- The experimental investigation highlights the significance of thermal history and deposition strategy in determining the quality of multi-pass WAAM builds using stainless steel.
- The COBOT system provided high-precision torch control, making it possible to isolate the effects of individual parameters such as inter-pass delay and hatch spacing.
- Controlled inter-pass reheating contributed to desirable microstructural transitions, improving fusion at the bead interfaces. However, insufficient cooling between passes increased the risk of grain coarsening and distortion.

Conclusions

- Microstructural evolution in WAAM is highly sensitive to heat accumulation during multi-pass deposition.
- Appropriate inter-pass delay and hatch spacing are critical for defect-free builds.
- COBOT-guided deposition enables precise control of layer positioning and thermal input.

Acknowledgments

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