INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
PhD-17 SHORT ABSTRACT OF THESIS

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SHORT ABSTRACT

Residual stress critically governs the structural integrity of wire-based directed energy deposition (DED) thin walls. This work presents an integrated experimental computational AI framework to tailor residual stresses in CMT deposited 9Cr-1Mo steel. Experiments with diverse scanning strategies were combined with in-situ thermocouple measurements, XRD residual stress analysis, and microstructural mechanical characterization, revealing a martensitic matrix with δ-ferrite and strengthening carbides. A coupled thermal–metallurgical–mechanical (TMM) model incorporating martensitic transformation strain predicts residual stress evolution, showing that prolonged inter-layer dwell time intensifies tensile stresses, while optimized dwell time, linear energy density, and advanced scanning strategies (bi-directional, spiral-in, mixed) enable effective stress mitigation. Physics-informed deep learning surrogates trained on FE and experimental data achieve high predictive accuracy, with temporal convolutional networks (TCN) providing the best performance and enabling inverse design of deposition parameters for targeted stress control. This unified experiment TMM AI framework enables intelligent process design for residual stress minimization and structural performance enhancement in wire-arc additively manufactured 9Cr-1Mo steel.