Efficient cooling time optimization in Wire Arc Additive Manufacturing using a multi-layer reduced order model

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Abstract

Additive manufacturing (AM) has transformed the industry by enabling the production of complex geometries and parts with customized properties. Among various AM techniques, wire arc additive manufacturing (WAAM) stands out due to its high deposition rate and low equipment cost. However, WAAM's complex thermal history poses challenges for real-time simulation, essential for online process control and optimization. Consequently, experimental optimization remains the state-of-the-art approach. A critical parameter to optimize is the cooling phase duration, which prevents structural overheating, controls the molten pool size, and influences the mechanical properties of the final product.
For efficient cooling time optimization, a fast-to-evaluate model of the temperature field during multi-layer deposition is necessary. This study proposes a reduced order model (ROM) using the proper generalized decomposition (PGD) method (1) as a powerful tool to minimize computational effort. Given the moving heat source in WAAM processes, a mapping approach (2,3) is employed to achieve a fully separated representation of the temperature field. Building on the authors' previous one-layer approach (4), this contribution extends the model to multiple layers through enhanced mapping and compression techniques. The compression reduces the total number of PGD modes as the number of layers increases. The extended mapping allows computations with a fixed mesh over the simulation time, in contrast to standard methods such as the element birth technique.

For cooling time optimization, the cooling duration of each layer is incorporated as PGD variables, enabling time-efficient computation of the temperature field for varying cooling times. The developed ROM is applied to optimize the cooling time of a multiple layer example. Therefore a 5-10 layer wall structure is investigated using the austenitic stainless steel 1.4404 (AISI 316 L). The resulting cooling times and the efficiency of the approach are discussed.

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