Simplified Thermo-mechanical Modelling For The Wire Laser Additive Manufacturing Process

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Abstract

Wire laser additive manufacturing (WLAM) is a process which enables to produce parts with complex geometries by successively adding layers of material. A wire-shaped filler metal is melted by a moving laser beam to form a deposit. Thanks to its high deposition rate, WLAM can be used to manufacture large parts with a better surface roughness than the wire arc additive manufacturing (WAAM) process, making it attractive to many industrial sectors (naval, aeronautical, automotive, etc.).

However, like all processes, it has its limitations. The generation of stresses during manufacturing can deform parts and induce residual stresses that potentially degrade parts fatigue life. To overcome these aspects, the fabrication with manufacturing processes involves a lengthy experimental phase to identify deposition strategies and machine parameters, leading to costly scrapping rate.

Therefore, numerical simulation is seen as a promising solution to this problem. However, despite the advancement of multiphysics models that can accurately predict existing phenomena, the high computational costs remain a significant challenge for large-scale parts. As a result, these models must be simplified before their applications in industrial settings.

While there are only a few part-scale models for the WLAM process, simplified modelling techniques have been introduced in recent years for WAAM, direct energy deposition, and powder bed fusion processes. These approaches mainly rely on "Flash Heating" or "Inherent Strain" methods [1][2]. Most of the research concentrates on predicting part deformations, with less emphasis on residual stresses, despite the latter being essential for predicting structural lifetimes.

This work presents simplified part-scale numerical models aimed at predicting the final part geometry and the residual stresses it contains. By adapting the "Flash Heating" and "Inherent Strain" strategies, the aim is to achieve a compromise between simulation cost and prediction accuracy when simulating a complete part.

Reference

[1] J. Wang et al., « A line-based flash heating method for numerical modeling and prediction of directed energy deposition manufacturing process », J. Manuf. Process., vol. 73, p. 822-838, janv. 2022

[2] F. Poulhaon, S. Springer, T. Gruber, M. Lasnik, B. Oberwinkler, et P. Joyot, « Incremental inherent stress model for the fast prediction of part distortion made via wire arc additive manufacturing », J. Manuf. Process., vol. 121, p. 136-149, juill. 2024

Figures used in the abstract

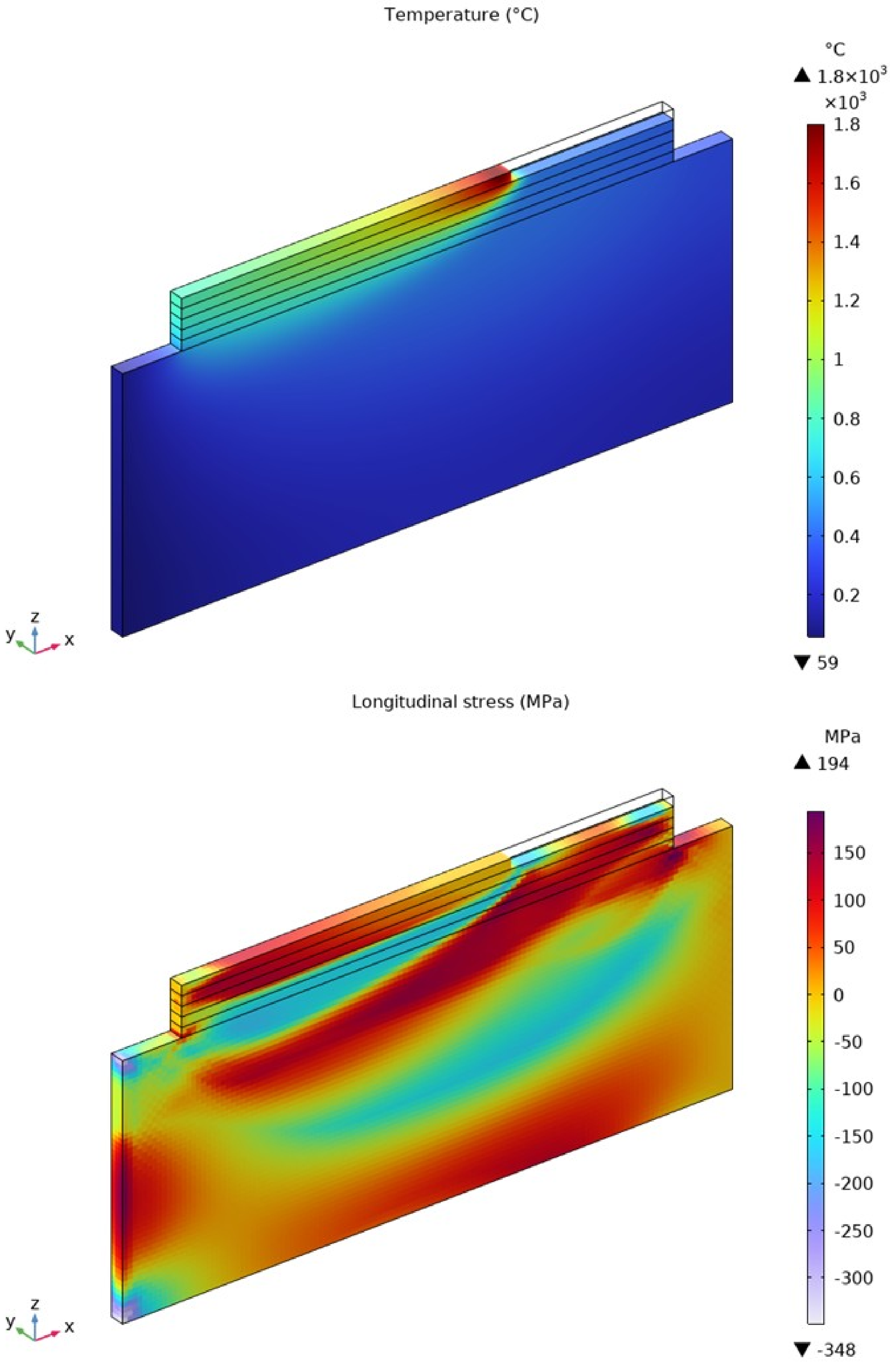

Figure 1 : Temperature and stress fields during fabrication of a five-layer wall by wire additive manufacturing process