NUMERICAL MODELLING OF LARGE FORMAT ADDITIVE MANUFACTURING TO ENHANCE LAYER ADHESION AND REDUCE WARPAGE IN GLASS FIBER REINFORCED ABS STRUCTURES

Pablo Castelló[1a*], Javier Bas[1], César García-Gascón[1], Juan A. García-Manrique[1], Francisco Chinesta[2]

Design for Manufacturing Research Institute (IDF). Universitat Politècnica de València, Valencia, Spain[1]
PIMM Laboratory, Arts et Métiers Institute of Technology, CNRS, ENSAM, Paris, France[2]
*pabcaspe@upv.edu.es

Keywords: Large Format, Additive Manufacturing, Layer Adhesion, Numerical Modelling.

Abstract

Large Format Additive Manufacturing (LFAM) is gaining prominence in sectors like aerospace and automotive, where there is a demand for producing large, complex components with precise tolerances. The integration of composite materials in material extrusion (MEX) processes is further enhancing the ability to create stronger, stiffer, and lighter structures. However, a significant challenge in LFAM is warpage. This issue arises from thermal gradients between adjacent layers, leading to residual stresses that distort the final part. A key contributor to this problem is poor layer adhesion, which compromises the structural integrity [1].

As found in previous studies, extruder and bed temperature, as well as layer width and height [2], within others, are identified as some of the main factors affecting the layer adhesion. More precisely, understanding and modelling the temperature evolution of the layers is of great importance to explain temperature effects on layer adhesion quality. Three parameters that affects the thermal behaviour per layer and that could be easily modified in the LFAM machine used (Super Discovery 3D) are: layer deposition time [3], nozzle temperature and extrusion factor. Hence, a parametric study is proposed to understand the influence of these 3D printing parameters on the thermomechanical properties of the printed structure. Therefore, a set of experiments is designed, where the temperature evolution of the whole printed structure is monitord by an infrared camera. Then, a series of tensile tests are performed over standardized specimens manufactured with a LFAM machine in ABS reinforced with 20% short GF. Loads are applied perpendicular to the printing direction to ensure that fracture results from failure in the adhesion between layers. This experimental method has been proved before [3].

In each of the studied cases, the microstructure of the material is studied using a Scanning Electron Microscope (SEM). The SEM images taken are processed to compute the short glass fibers dimensions and orientation. Using a software – called Digimat – a thermomechanical study is performed at the microscale. Finite Element Methods (FEM) are used by the software solver to compute the numerical simulation of the same tensile tests performed experimentally. This method, allows the microstructure characterization and the extrapolation of these micro-level mechanical properties by homogenization methods.

The previous microscopic model, is coupled with a numerical macroscopic model developed in Abaqus. The macroscopic model includes the thermal modelling and heat transfer scheme per layer, as well as the resulting residual stresses generated during material deposition. Together,

they compose an accurate numerical model that evaluates layer adhesion quality during the 3D printing of large-scale components using glass fiber (GF) reinforced ABS, as a function of the studied LFAM parameters. The model's accuracy will be validated by comparing its predictions with experimental results. This work is part of a Digital Twin (DT) framework, designed to replicate the LFAM process and predict warpage formation.

The main objective of this research is to model the thermomechanical behavior of parts in LFAM processes, as a results of layer adhesion quality. The model should enable the optimization of manufacturing parameters to maximize mechanical properties, reduce printing time, and minimizing internal stresses in the part. The following are expected to be obtained form the research:

- Optimal parameters for layer deposition
- Heat transfer numerical scheme
- Layer adhesion and warpage prediction

Acknowledgements

This work was supported by Generalitat Valencia (GVA) and Spanish Ministry of Science and Innovation. INVEST/2022/131, CIACIF/2021/286, PID2023-151110OB-I00 and CIPROM/2022/3.

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