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A NUMERICAL SIMULATION APPROACH FOR CONTINUOUS WIRE ENCAPSULATION ADDITIVE MANUFACTURING OF POLYMER AND SHAPE MEMORY ALLOY

Sidharth Sarojini Narayana[1*], Sampada Bodkhe[1]
[1] Laboratory of Intelligent Structures, Mechanical Engineering
Polytechnique Montreal, Montreal, Quebec, Canada
*sidharth.sarojini-narayana@polymtl.ca

Abstract

The field of multi-material additive manufacturing has witnessed growing interest due to its potential to create multifunctional structures with tailored properties, offering new solution for industries like aerospace, automotive and healthcare. One such process includes integration of shape memory alloy wires (SMA) into polymer for developing smart shape transforming structures with adaptive mechanical properties and enhanced functionality.

Continuous wire encapsulation additive manufacturing (CWEAM) is a form of coextrusion additive manufacturing, a process that allows simultaneous printing of multiple materials, presents a viable method for manufacturing these advanced structures. However, the process comes with complex challenges related to distinct thermal, chemical and mechanical behaviours of each material during the process. Additionally, optimizing process parameters like extrusion speed, temperature, and interface control is critical to ensuring strong interfacial bonding, consistent material properties, and desired structural performance in the final product.

Numerical simulation can offer a viable solution to address these challenges by predicting material interactions, optimizing process parameters, and ensuring the desired performance of the final part in the co-extrusion printing process. Although, there has been a good progress in numerical modelling and process optimization of structural polymers and materials, there has not been any work in the field of fabrication of smart structures via multi-material additive manufacturing. Furthermore, there remains a significant gap in the availability of accurate simulation tools specifically to model coextrusion process involving an SMA (high modulus) wire and polymer.

This work proposes a computational strategy to simulate the continuous coextrusion of an SMA and a thermoset polymer using COMSOL Multiphysics. The framework models fully coupled thermo-chemo-mechanical interactions using the finite element (FE) method. The simulation solves coupled mass, momentum, energy, and chemical species transport equations. The interface between the polymer and air is solved using the level set method for multiphase flows. The results will also demonstrate the solidification of the polymer post extrusion. This is essential to retain the SMA in position within the polymer matrix post printing. The simulation results will provide insights into polymer flow patterns, temperature distribution, chemical reactions, and material deformations (both wire and the polymer) during coextrusion.

The work will result in the precise control over processing parameters to achieve final part with desired mechanical and functional characteristics, offering a robust tool for process optimization. This computational approach reduces the reliance on extensive experimental trails, accelerating the design and development of advanced smart composite structures.