Impact of Biobased Microvascular Networks in Advanced Composites

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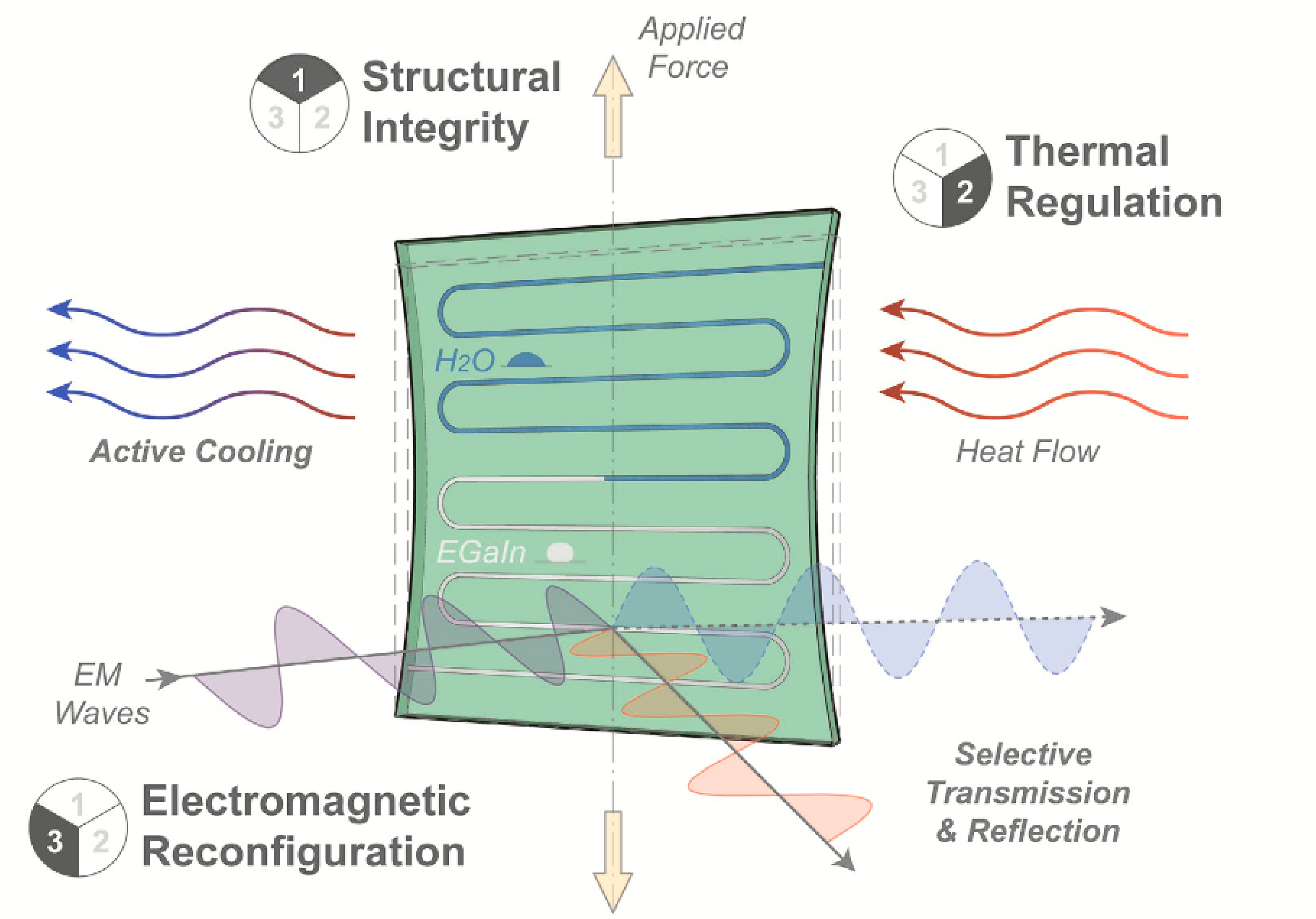
This project explores how integrating nature-inspired microvascular structures into fiber-reinforced composites like IM7/977-2 carbon fiber/epoxy enhances their thermoregulatory, mechanical, and rheological properties, emphasizing the intersection between synthetic and natural systems in engineering materials.



01. Introduction

In this study, we explore the potential of nature-inspired design principles to enhance aerospace and structural materials. Our focus is on investigating how integrating microvascular networks can improve thermoregulation and structural integrity in composites. By addressing questions regarding the influence of these networks on thermal properties, mechanical behavior, and potential applications, our research aims to offer novel insights to advance lightweight, high-strength materials across various industries.

02. Objective

How does the geometry of different microvascular networks affect the performance of the material?

Related literature

Devi, U., Pejman, R., Phillips, Z. J., Zhang, P., Soghrati, S., Nakshatrala, K. B., Najafi, A. R., Schab, K. R., & Patrick, J. F. (2021a). A Microvascular-Based Multifunctional and Reconfigurable Metamaterial. Advanced Materials Technologies, 6(11), 2100433. https://doi.org/10.1002/admt.202100433

03. Methodology

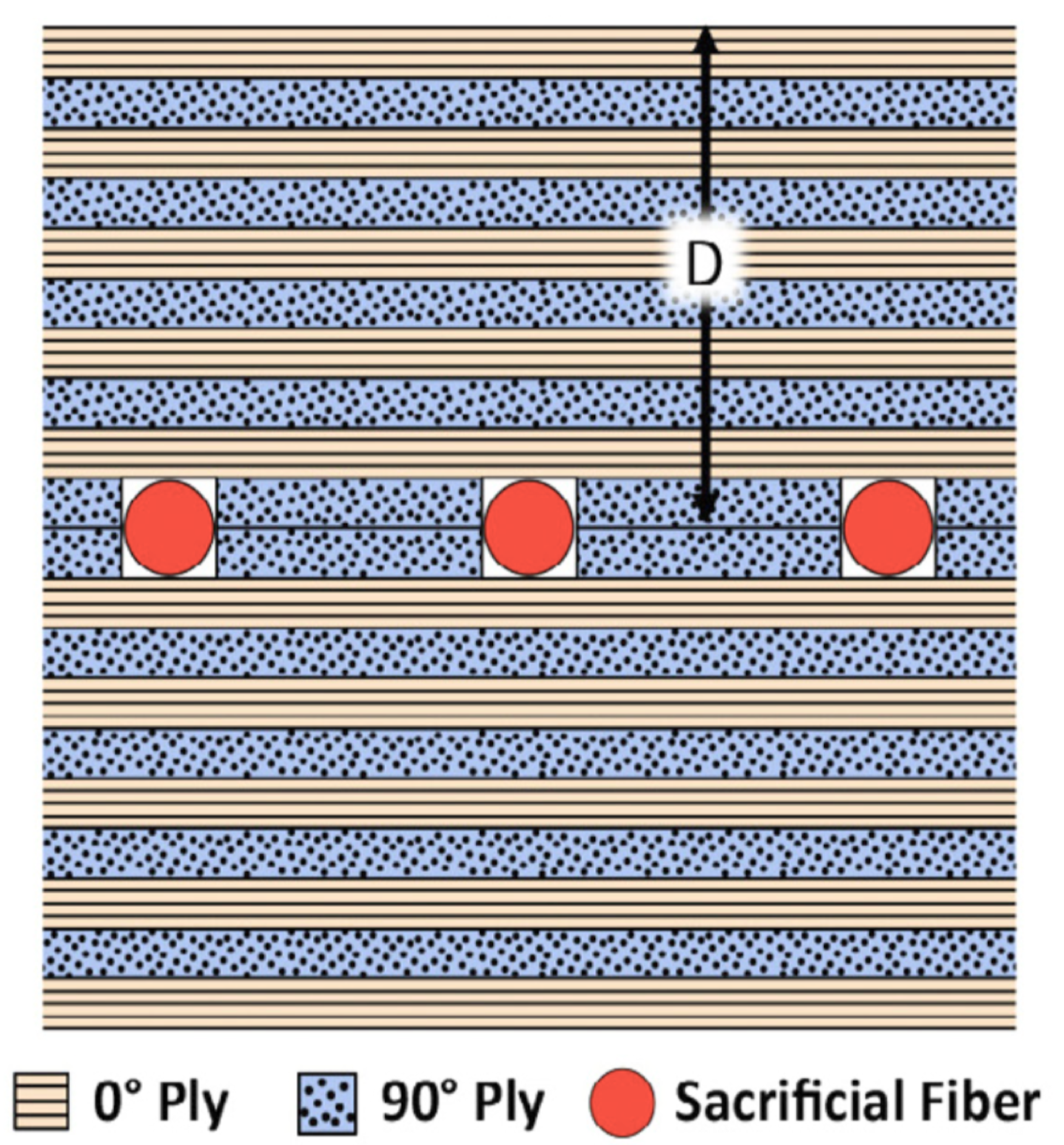
This project relies entirely on the following steps. Three different microavscular netwyorks are 3D printed and the samples are fabricated using various techniques before testing.

- **3D Print VaSC**
- **Composite Layup**
- **Curing**
- **Testing**

Coppola, A. M., Warpinski, L. G., Murray, S. P., Sottos, N. R., & White, S. R. (2016). Survival of actively cooled microvascular polymer matrix composites under sustained thermomechanical loading. Composites Part A: Applied Science and Manufacturing, 82, 170–179. h

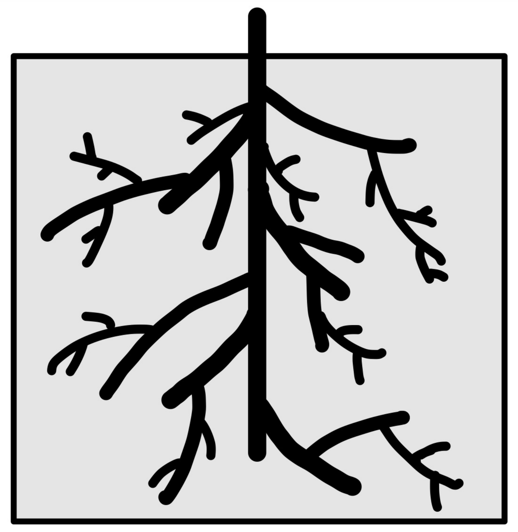
04. Materials

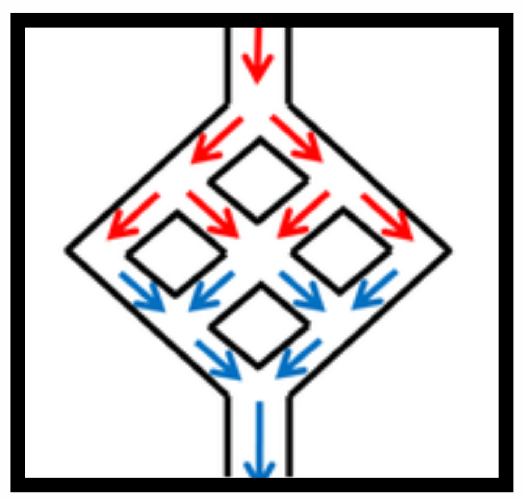
This study aims to investigate the influence of various thermoregulatory micro-network structures on the performance of carbon fiber/epoxy laminates composed of IM7 carbon fibers and 977-2 epoxy matrix. Polylactic acid (PLA) sacrificial components are chosen for their suitability in direct ink printing and sustainability. The experimental process involves designing and 3D printing three different network designs using CAD software and PLA filament, determining laminate stacking sequence and orientation, and placing sacrificial components between carbon fiber-epoxy prepreg laminates. Curing in an autoclave at temperatures ranging from 130-200 ℃ is conducted, followed by examination of sacrificial component microchannels' inner roughness. Thermal testing using a temperature-regulating agent and digital twin examination, mechanical tests at various temperatures considering epoxy's viscoelastic behavior, and potential rheological tests are performed. Comparison and analysis of results across different structures aim to elucidate the strengths and weaknesses of each network pattern.

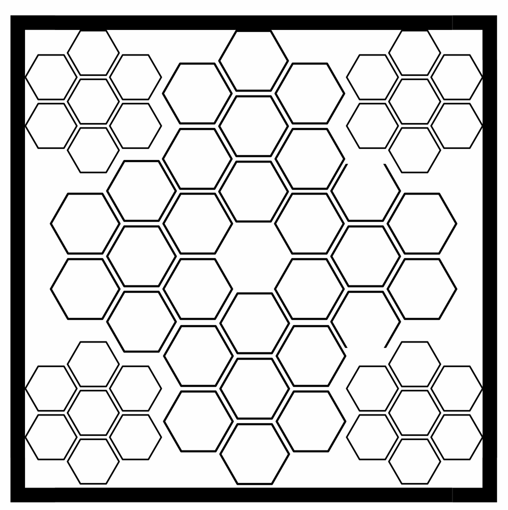


05. Microvascular Structures

We examine the effectiveness of three microvascular networks—leaf venation, chameleon skin capillaries, and honeycomb—in enhancing advanced composites. Inspired by nature's efficiency, each network offers unique potential for improving thermoregulation and structural integrity. Through systematic testing, we aim to identify their strengths and limitations, contributing to the development of superior materials for diverse applications.


Leaf Venation


Chamelion Skin Capillaries


Honeycomb

06. Conclusion

We hypothesize that each microvascular structure will yielddifferent material properties. The use of wider and more scarce micro networks may result in lower thermal regulation properties but higher structural integrity. Whereas, narrower but more abundant micro network systems may have better thermal regulation but will decrease the structural integrity of the material. There may be a decrease in interlaminar shear strength ILSS.