

Title: Data-Driven Interfacial Engineering of Multiscale Structures in Extreme Environments
Defense Date: 11/08/2024
Defense Time: 9:00 am to 11:00 am
Location: Material Research Building (MRB) Room 114

Abstract:

Composites are currently utilized in aerospace, automotive, marine, and infrastructure, and their exposure to harsh environments is a reality. Harsh conditions, such as extreme temperatures and moisture, can accelerate the aging process of the fiber/matrix adhesion, resulting in decreased load transfer efficiency over time. The interfacial shear strength (IFSS) plays an important role in predicting the mechanical performance of composite materials. Therefore, understanding the behavior of IFSS under such conditions is essential for ensuring the structural integrity and longevity of composite structures in real-world applications. Various mechanical techniques offer unique insights into interfacial behavior under different loading conditions. However, the absence of standard methods for these techniques creates discrepancies between results and limits a reliable prediction of bonding strength between materials.

This dissertation focuses on utilizing data-driven techniques to investigate the influence of environmental exposure on the IFSS of nanomaterial and micromaterial interfaces. The proposed research includes developing a horizontal mold and a custom mechanical fixture to manufacture and test pullout samples using the same design. The effectiveness of custom methods was validated by testing the IFSS between different reinforcements with thermoset resins. Overall, this research aims to contribute to the optimization of composite design and manufacturing processes to quantify interfacial adhesion using minimal amounts of materials. In addition, this research explores the diverse applications of data-driven techniques to optimize processing parameters and create predictive models to identify failure mechanisms.

Data-driven techniques provide better insight into materials lifecycle that help create strategies for mitigating environmental degradation effects on IFSS.

This further includes selecting the appropriate data-driven techniques to study interfacial bonding degradation under different environmental conditions. Specialized equipment was used to mimic specific environmental scenarios. The influence of environmental factors on surface morphology, matrix properties, and adhesion mechanisms will be covered in this report. The results provide valuable insights into the degradation mechanisms affecting interfacial bonding and shear strength in composites exposed to harsh environments. Moreover, predictive models derived from data-driven approaches facilitate the identification of bonding failure and understand relationships between controllable and uncontrollable factors.

This study investigates the interfacial shear strength (ISS) of polymer matrix composites (PMCs) subjected to extreme environmental conditions, including high temperatures, corrosive chemicals, and severe mechanical stress. The interfacial region is critical for the overall performance of PMCs, influencing their mechanical integrity and durability. Using a combination of experimental techniques and computational simulations, we evaluate the effects of temperature variations and chemical exposure on the interfacial bonding between the polymer matrix and reinforcing fibers. Through shear tests and advanced microscopy methods, we quantify changes in ISS and analyze failure mechanisms under different extreme conditions. Results indicate significant degradation in interfacial strength correlating with environmental factors, underscoring the importance of material selection and treatment in enhancing the performance of PMCs in demanding applications. The findings contribute to the design of more resilient composites for use in aerospace, automotive, and marine industries, where extreme conditions are commonplace.

This report presents a research proposal for testing nanomaterial and micromaterial bundle interfaces at different environmental conditions. Data-driven techniques and specialized equipment were used to mimic specific environmental scenarios. The influence of environmental factors on surface morphology, matrix properties, and adhesion mechanisms will be covered in this report. The results provide valuable insights into the degradation mechanisms affecting interfacial bonding and shear strength in composites exposed to harsh environments.