

Summary

The evolution of joining technologies represents a pivotal frontier in modern engineering. The ability to connect materials effectively has become fundamental to technological advancement. As industries in aerospace, automotive, renewable energy, and advanced manufacturing push the boundaries of material design, joining techniques have emerged as critical enablers of innovation, performance, and structural efficiency. This thesis begins by investigating an acid etching process designed to modify the surface of carbon fiber-reinforced polymer (CFRP) substrates to improve the shear strength of adhesive joints. The effectiveness of the treatment was evaluated through mechanical testing using Single Lap Joint (SLJ) and Single Lap Offset (SLO) configurations, providing insight into the influence of surface modification on joint performance. Building on this foundation, the thesis then proposes a comprehensive methodology to characterize the shear response of the adhesive material using several different mechanical tests, including torsional loading. An analytical model was developed for hourglass-shaped adhesive joints under torsion, initially based on an elasto-plastic shear behavior. The model's ability to extract realistic material properties was validated through comparison with A4PB and SLO test results. To increase its accuracy, the model was refined using a piecewise linear shear stress–strain distribution, enabling more precise identification of shear properties. To complement the analytical approach, in situ torsion tests were performed inside a tomography machine, with Digital Volume Correlation (DVC) employed to obtain the actual displacement field within the adhesive layer. These displacements, along with the traction–separation law derived from the analytical model, were used to build a finite element model (FEM) based on a cohesive zone approach. The FEM simulations reproduced the full stress–strain field in the adhesive joint under torsional loading, offering a detailed view of its mechanical response. This integrated approach combining surface treatment, experimental testing, analytical modeling, DVC, and FEM provides a robust framework for evaluating and optimizing the performance of adhesive joints in structural applications.