

Travail de fin d'études et stage[BR]- Travail de fin d'études : Design of Hybrid Composites for FS Race Car Monocoques :An Experimental and Numerical Approach[BR]- Stage

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Master's Thesis
for the degree of Master of Science in Mechanical Engineering
with specialization in Sustainable Automotive Engineering

Design of Hybrid Composites for FS Race Car Monocoques:
An Experimental and Numerical Approach

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The Formula Student competition challenges student teams worldwide to design, build, and race single-seater formula racing cars, pushing the limits of innovation in automotive engineering. As ecological concerns become increasingly prominent, the need for greener materials in high-performance vehicles is essential. This thesis focuses on the design of a more sustainable hybrid composite lay-up for a Formula Student race car monocoque, aiming to achieve mechanical properties comparable to traditional carbon fiber while maintaining a similar weight. The research introduces flax fibers as a natural alternative, integrated into carbon-flax hybrid composites that exhibit enhanced crashworthiness, especially in critical zones such as the front bulkhead. For safety reasons, all these composite parts of the monocoque that may be subjected to impact must undergo perimeter shear testing.

The investigation was structured into two primary components. The first component involved an experimental study assessing the influence of stacking sequence and flax fiber mass fraction on the mechanical properties of the hybrid composites. Vacuum-assisted resin infusion was employed to manufacture high-quality samples, while perimeter shear tests were conducted to evaluate their resistance to puncture and impact. Results indicated that hybrid composites with flax fibers placed in the outer layers, and alternating carbon and flax fibers within the lay-up, demonstrated superior resistance compared to traditional carbon fiber composites. A specific configuration achieved a peak force of 27454 [N] with just 10 layers, thus allowing the theorization of hybrid configurations for the front bulkhead, leading to a reduction in its mass of 22% and its CO₂ footprint by over 43% compared to the current lay-up.

The second component of the research focused on developing a reliable numerical model to simulate the perimeter shear test using Ansys. The model was designed to replicate experimental conditions, and the objective was to obtain the force-displacement curves from multistep simulations and determine the first ply failure of the sample. The simulation incorporated frictional contacts and accounted for large deflections, achieving a high degree of accuracy in predicting force-displacement curves. Therefore, the dependency on extensive laboratory testing is reduced and valuable insights into stress distribution are provided.

All the steps related to a new testing strategy have been thoroughly covered in this work, from the lay-up design to experimental testing, including numerical simulations and sample fabrication. The conclusions of this thesis suggest that carbon-flax hybrid composites are promising materials for use in critical areas of a monocoque structure, such as the front bulkhead, which are subjected to high impact loads and that must resist perforation. Although these results are promising, further research is required to refine the damage modeling and optimize the hybrid composite properties for practical applications in Formula Student vehicles.

Keywords: Hybrid composites | Carbon fiber | Flax fiber | Perimeter shear test | Damages modeling

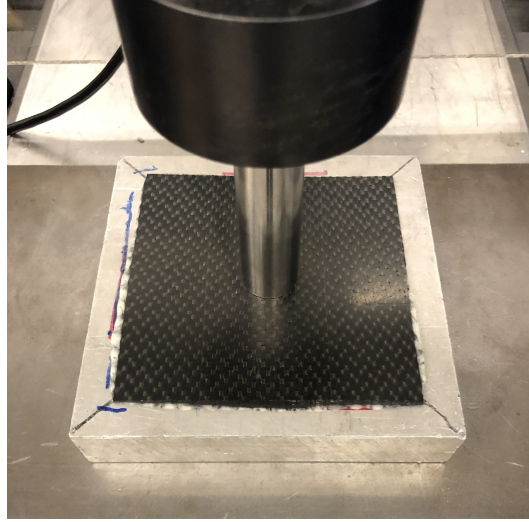


Figure 0.1: Sample under experimental conditions for the perimeter shear test.

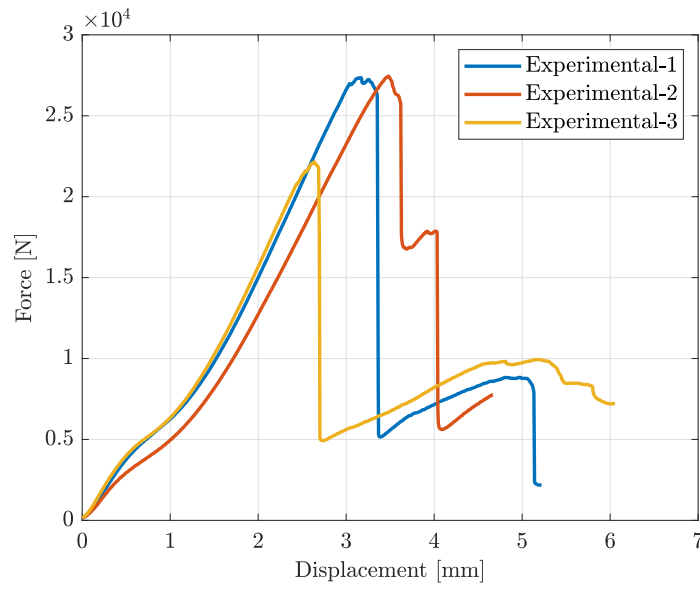


Figure 0.2: Force-displacement curves of experimental data for the hybrid samples 5b. The displacements are normalized.

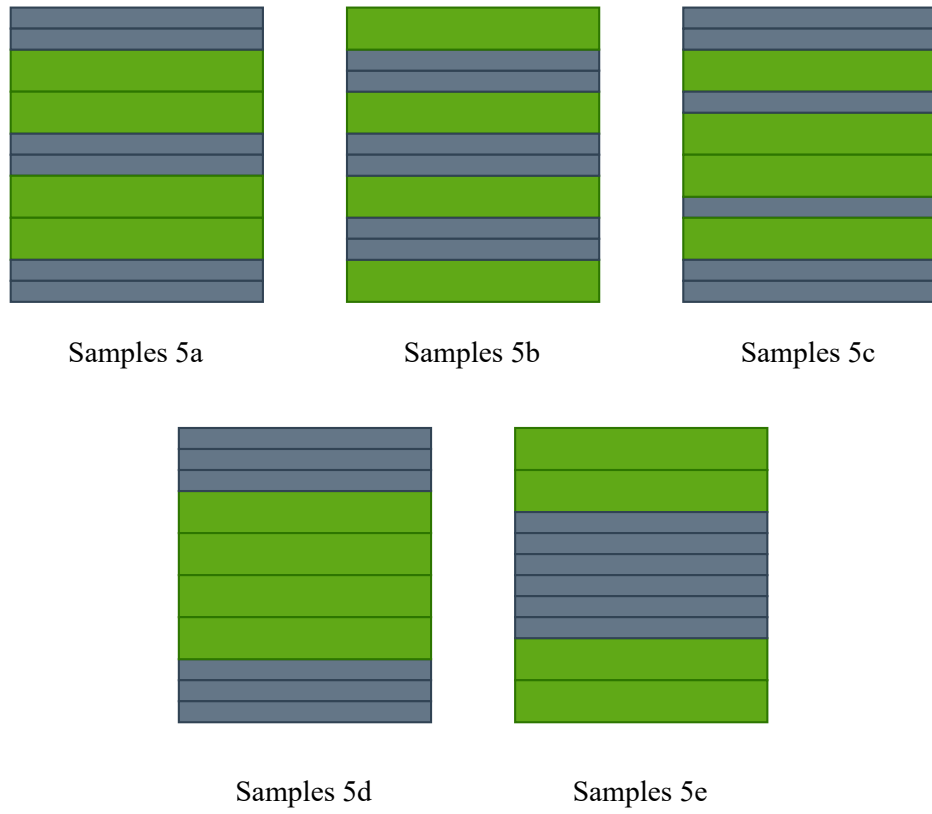


Figure 0.3: Illustration of the stack-up sequences of samples 5.

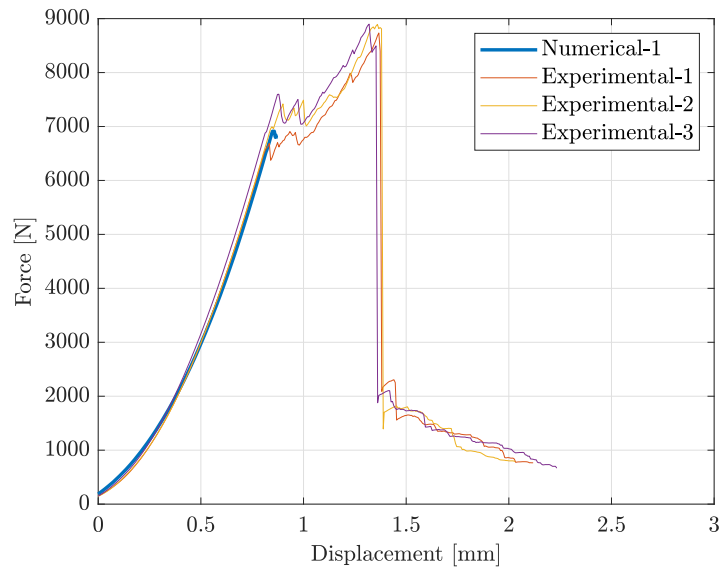


Figure 0.4: Force-displacement curves of experimental and numerical data for samples 8c. The displacements are normalized.