Design and Manufacturing of a Carbon Fiber Accumulator

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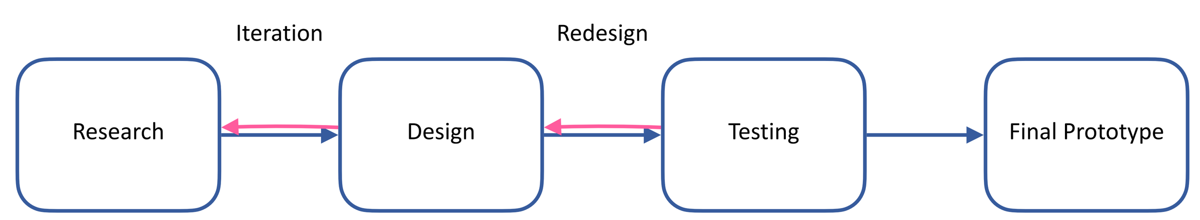
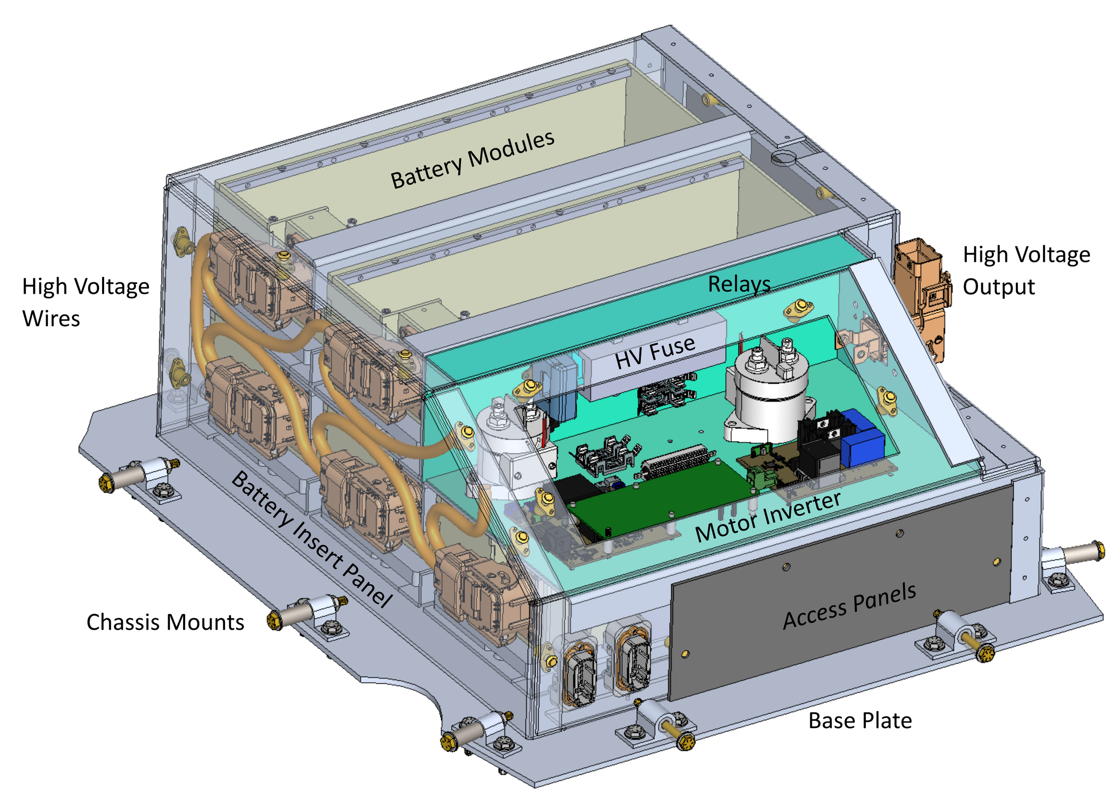
Overview

The objective of this project is to develop composite materials for an battery pack container. Key steps include material selection, geometric design optimization, manufacturing composites, and testing structural samples. The target is a finalized container design based on comprehensive research and testing results, ensuring optimal performance, safety, and rule compliance for the 2025 FSAE EV competition.

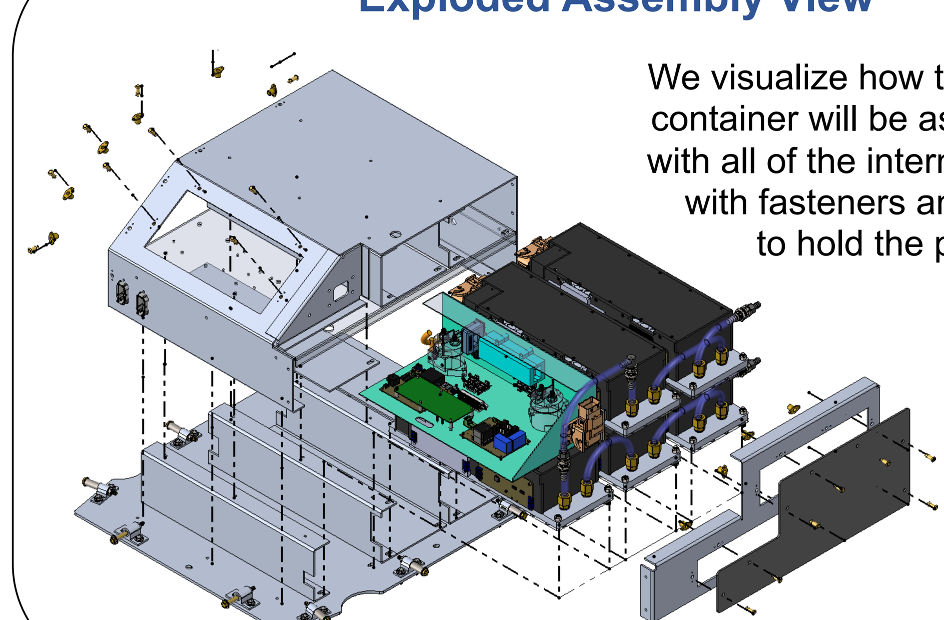
Accumulator Design



The design philosophy begins with the rules examination and looking into theory about material properties and practical construction. The rules provide external constraints that are met critically. Consultation with electrical teams during iteration and redesign provides feedback to meet necessary goals. While design occurs, prototype panels were constructed to inform what is possible and allow for more practical redesign. Through this process, we optimize over the design constraints while meeting critical requirements to pass safety inspections and provide space for other teams to find performance.



Exploded Assembly View



We visualize how the accumulator container will be assembled along with all of the internal components with fasteners and epoxy bonds to hold the panels together.

Discussion

The results we obtained show that carbon fiber is sufficiently strong for our applications. This however, comes at the cost of manufacturing complexity, which considering the capabilities of the team, may not be ready for the car this year. As the team matures and and obtains access to better facilities and tools, structurally regulated carbon fiber components may become considered again.

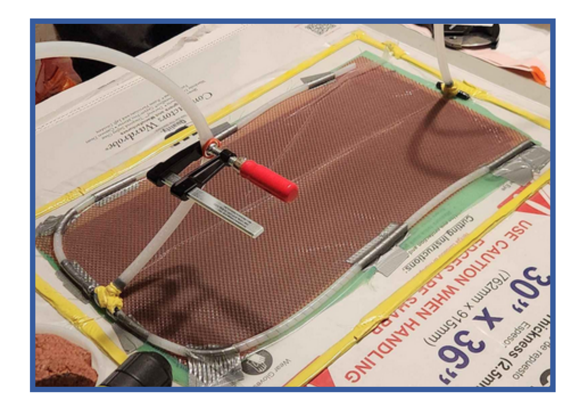
Lamination Theory

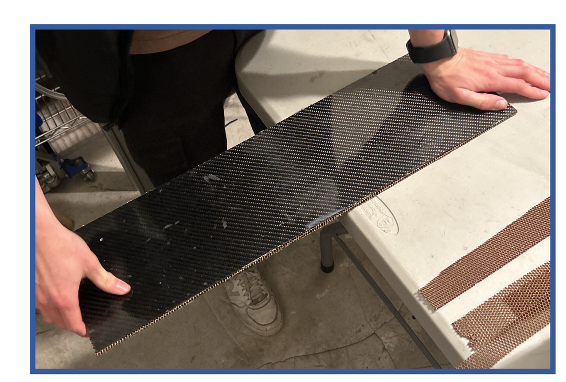
Composite materials are composed of a reinforcement (carbon fibers) held together by a matrix (polymer resin). Dry CF fabrics are classified by their weight and weave pattern, while resins are classified by viscosity and strength. Fiber fabrics are extremely strong in tension, while resins are strong in compression and shear. The orientation of fibers in the composite gives rise to anisotropic behavior that can be corrected by laying different orientations of fabric.

Manufacturing Schema

Composite fabrics must be impregnated with resins without any air or vacuum inclusions. Coating layers of fabric sequentially with resin, known as a wet lay, is the most accessible method but is susceptible to impurities so it cannot be used for structural components. Pre-impregnated CF is partially cured and is used for high quality structural components, but is costly and difficult to work with. We explore the use of vacuum-assisted resin transfer molding, or resin infusion, to fabricate structural parts without the cost of traditional pre-preg.

Test Panel

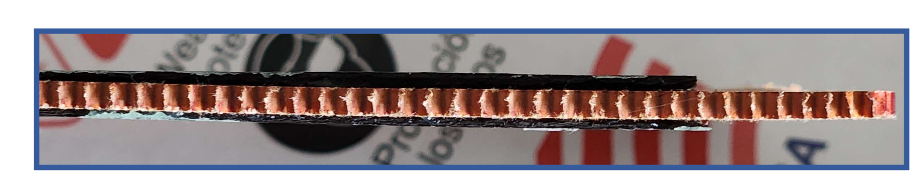




Above: Carbon Fiber Skins (four ply) resin infusion setup and finish

Left: Nomex Sandwich panel strengthened for bending loads.

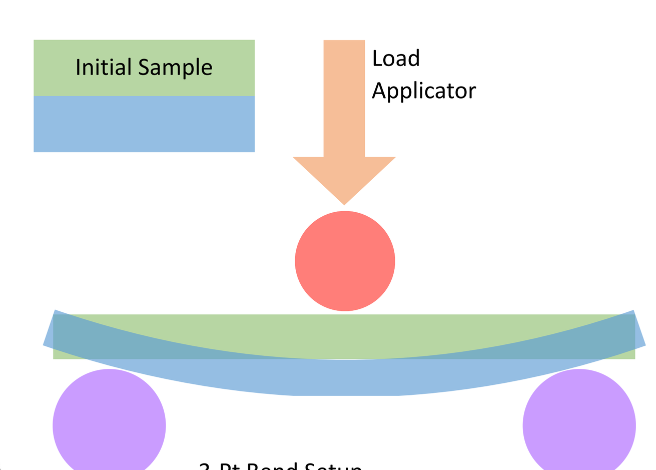
Below: The nomex honeycomb in shown bonded to two skins



Three Point Bend Test

Preparation

- Sample dimensions are width:138 mm x length: 500 mm
- Load applicator specs, metallic rod with 50mm radius



Goals

- We choose thickness plate
- Results used to derive stiffness, yield strength, ultimate strength and absorbed energy properties
- We need to prove that our material is strong enough for the

$$\text{Deflection } \delta = \frac{PL^3}{48EI}$$

$$\text{Flexure Modulus } E = \frac{PL^3}{48\delta I}$$

Acknowledgements

We would like to thank URCA and Anita Stahl for providing the opportunity to conduct undergraduate research along with our faculty advisor Kirk Fields and the entire Mechanical Engineering Department for the access to space and testing facilities they have enabled us to use.

FSAE Accumulator

High Voltage Low Weight

Thomas Yu | Matthew Lin | Tim Schmuelling | Raaghav Thirumaligai | Dylan Pratt

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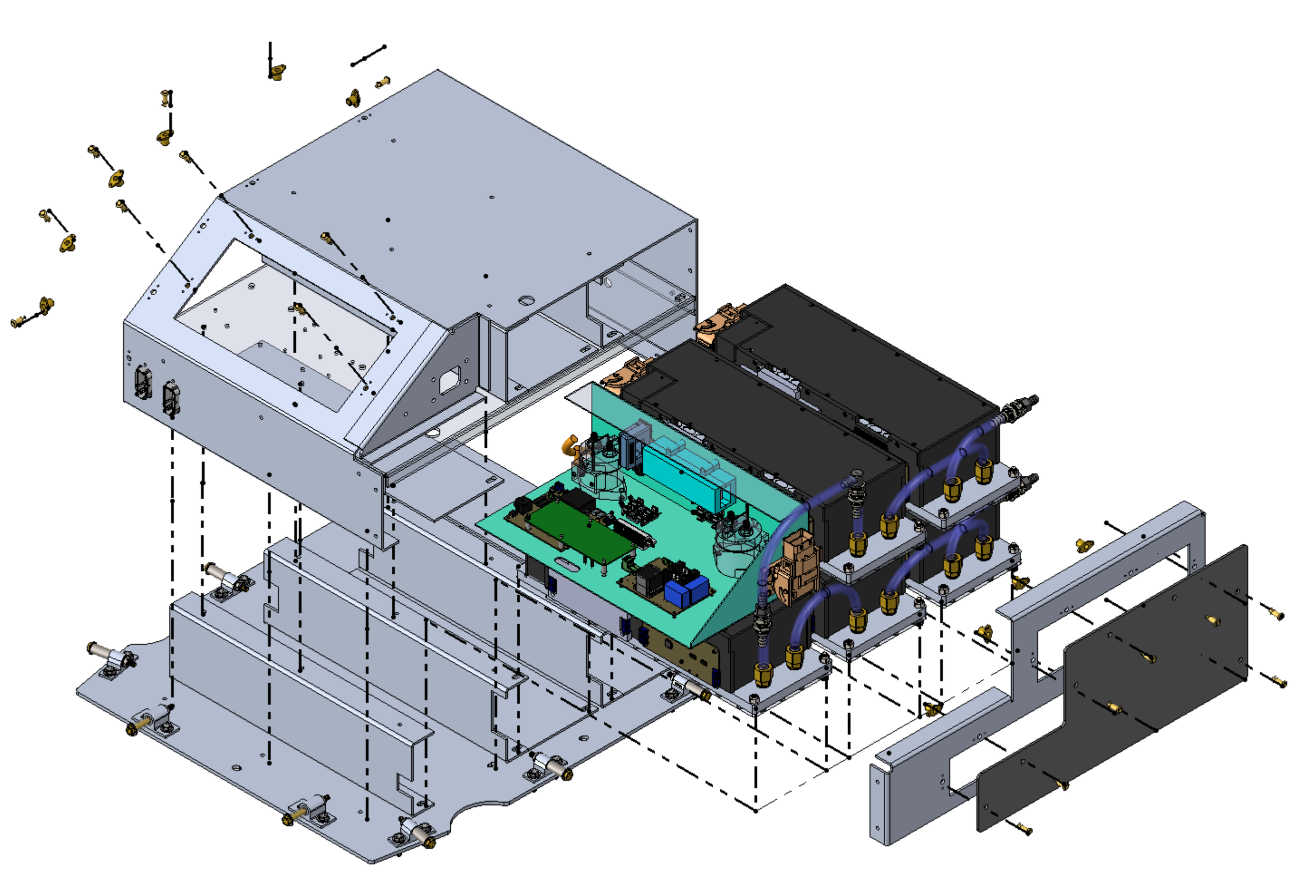
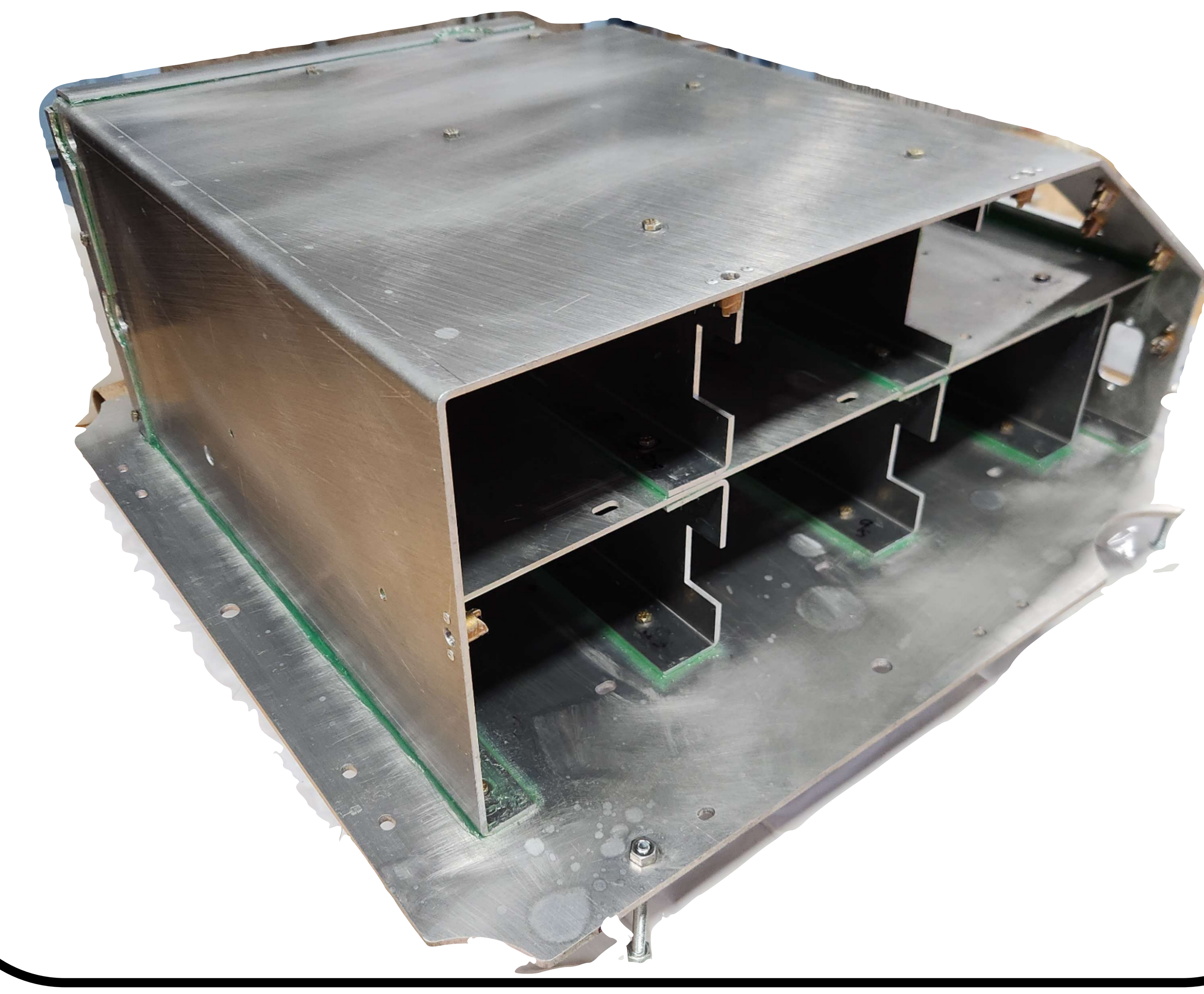
Exploded View



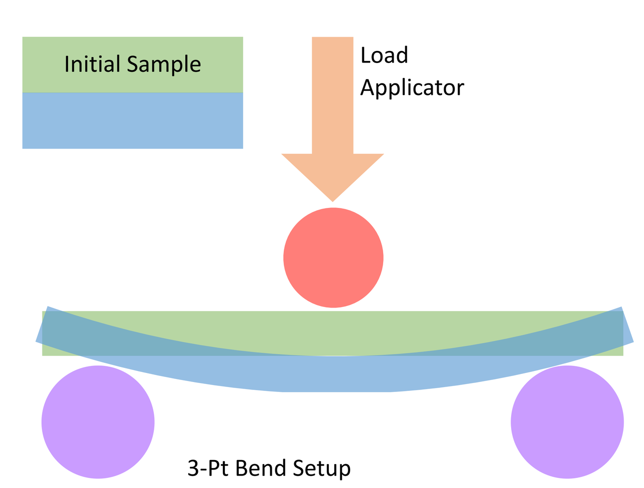
Bonded Container

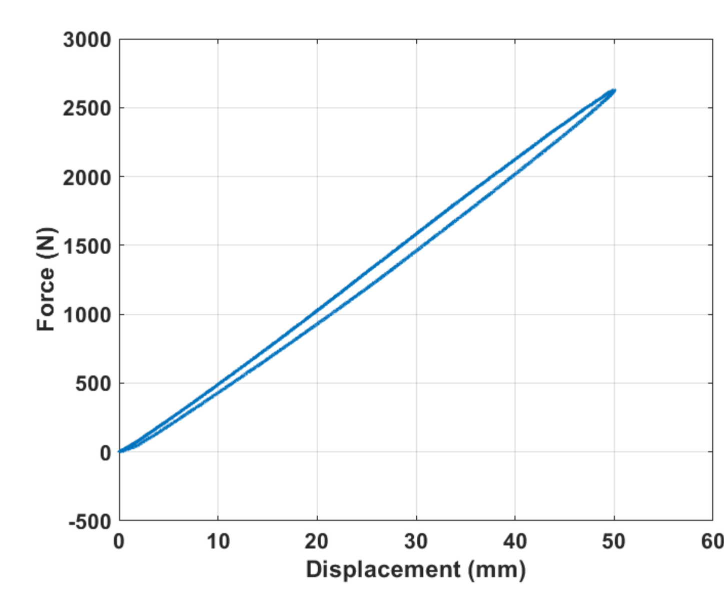


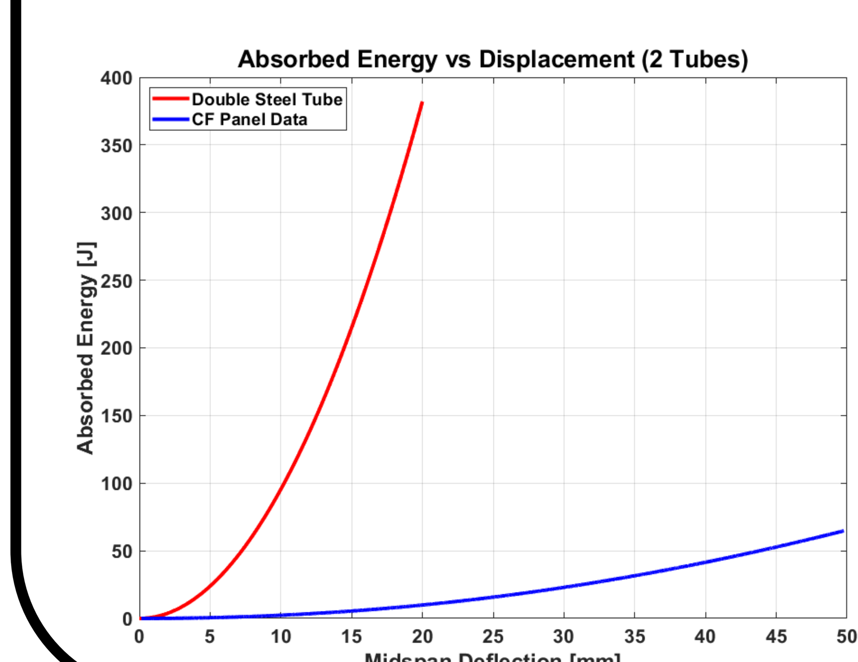
Carbon Fiber Testing

Three Point Bend Test

The measured deflection shows elastic behavior of the carbon fiber test panel.



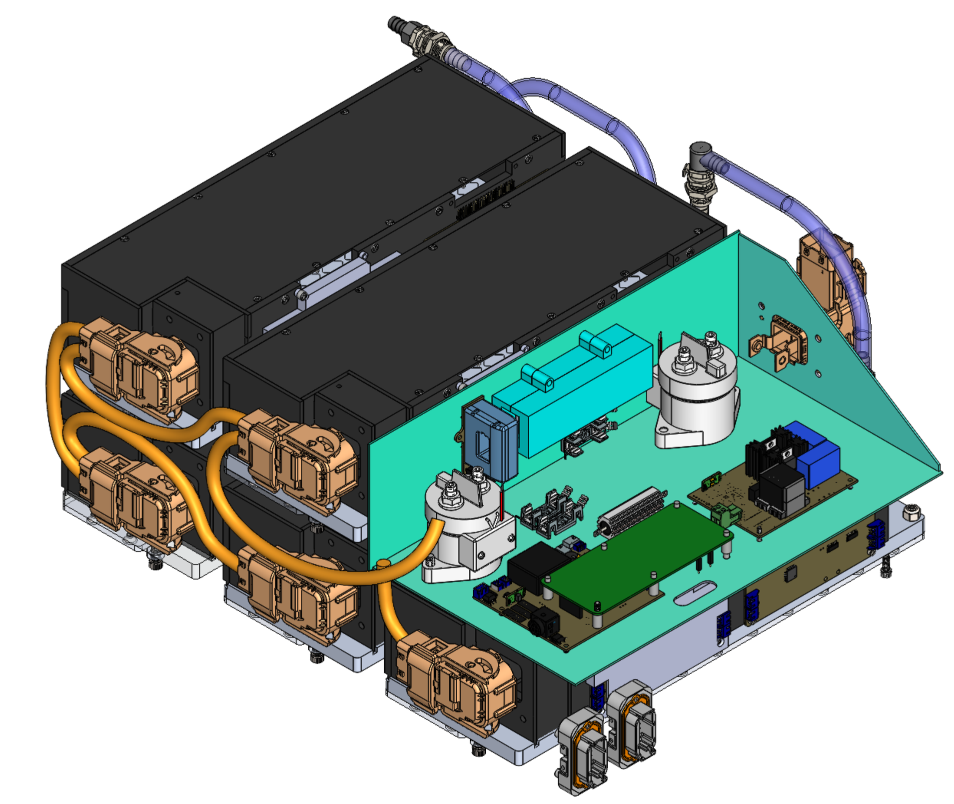




Energy Absorption

Compared to an ideal steel panel, the carbon fiber absorbs much less energy.

Key Components



5 battery segments in a 28s3p configuration of Li-ion cells are packaged in the tractive system accumulator container with an additional 2 compartments for mounting HV electrical components including relays, fuses, ACU, and DC-DC converter.

Conclusion

The experimental results obtained from the 3-point bend test on the vacuum assisted resin transfer moulding carbon fiber sandwich panel show promise with 50mm elastic deflection with hysteresis in the loading and unloading. Improvements can be made in future years by improving the core-skin thickness ratio and expanding the composite testing suite to include lap shear, T-peel, and other tests required for FSAE electric's composite structural equivalency spreadsheet.

For 2025, our team opted for bent aluminum 5052 aluminum panels that are bonded together with a two-part Pro-set epoxy at the flanges, which serves as a stepping stone for future years manufacturing a carbon fiber accumulator container. This was chosen over welded, riveted, or bolted panels to avoid poor tolerance due to welding and an excessive amount of fasteners and therefore over constraining of panels due to FSAE electric's SES requirements.

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