Knowledge Transfer on Composite Materials

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Abstract

This report documents the process of learning, applying, and validating composite material techniques for use in a solar car project. With no prior experience in composites, the work focused on understanding material behavior, fabrication methods, and basic testing approaches. Composite sandwich structures were designed and manufactured for a battery box, and a scalable manufacturing method was developed for the aeroshell. Wet lay up, vacuum bagging, and mold making techniques were explored through hands on fabrication. Mechanical testing following ASTM standards was conducted to validate design decisions, and preliminary simulation work was performed using ANSYS. The report serves as both a record of accomplishments and a reference for future teams working with composite materials in the solar car project.

1 Introduction

Composite materials are engineered by combining two or more distinct materials to create a structure with improved properties such as higher strength, lower weight, or increased durability. A common example is fiber reinforced polymer (FRP), which consists of reinforcing fibers such as fiberglass or carbon fiber embedded in a polymer resin matrix. These materials are widely used in aerospace, automotive, and marine applications where weight efficiency and mechanical performance are critical.

This report focuses on how composite materials were applied in the solar car project and what was learned throughout the process. Rather than emphasizing the theory of composites alone, the work highlights practical fabrication methods, testing approaches, and lessons learned through experimentation.

2 Relevance to the Solar Car

Composite materials are well suited for solar car applications due to their high strength to weight ratio. Because solar energy is limited, minimizing vehicle mass directly improves efficiency and performance. The research focused on two primary components:

- The battery box, which houses and protects the battery pack
- The aeroshell, which forms the aerodynamic outer surface of the vehicle

3 Research Goals

The primary objective of this project was to build foundational knowledge of composite materials and apply that knowledge to real components. Specific goals included learning basic composite theory, exploring fabrication techniques such as wet lay up and vacuum bagging, manufacturing full scale and prototype parts, and validating designs through mechanical testing. A secondary goal was to explore simulation tools to predict material behavior and guide future design decisions.

The summer work can divided into three main areas:

- battery box,
- aeroshell and
- testing and simulations

Each area is discussed in detail in the following sections.

3.1 Battery Box

The battery box is required to support approximately 60 pounds of load while remaining electrically non conductive. To meet these requirements, a sandwich composite structure was selected. The design consists of fiberglass 7 oz facesheets with four total plies, two on each side, a Divinycell H60 foam core, and epoxy resin. Each side of the box was manufactured as a flat panel and later joined to form the final structure.

3.1.1 Manufacturing Method

The wet lay up method was used to fabricate the composite panels. In this process, dry fabric is manually saturated with mixed epoxy resin directly on the mold surface. A smooth plastic board was used as a flat mold for the rectangular panels. The mold serves as the negative shape that defines the surface finish of the composite part.

3.1.2 Preparation

It is crucial that all materials are laid out and cut to the appropriate proportions before the process is started. Preparation is key to achieving a smooth and well manufactured composite part.

Figure 1: Materials cut and prepped for wet layup process

3.1.3 Mold preparation

A clean glass sheet or flat plastic board was prepared as the working surface. Multiple coats of chemical release agent were applied to ensure easy demolding

3.1.4 Wet Lay Up Process

- Apply a thin layer of resin directly onto the release coated surface.
- Lay the first fabric layer and use a brush or squeegee to wet it thoroughly.
- Continue layering to the desired number of plies for the bottom skin, applying resin between each layer.
- Apply resin to one face of the foam core and press it onto the wetted fabric stack.
- Repeat the wetting and layering process for the top skins.
- Avoid excessive resin to keep the laminate lightweight and ensure each layer is fully wetted.

3.1.5 Vacuum Bagging

Figure 2: Vacuum bagging setup for composite curing

- After lay up, apply peel ply, followed by an optional perforated release film for higher vacuum levels, and then a breather layer.

- Seal the part inside a vacuum bag using sealant tape.
- Install a vacuum port and hose, ensuring that the breather layer is positioned beneath the port.
- Apply approximately 20 percent vacuum, corresponding to about 5 inHg, using a regulated vacuum pump.
- Maintain the vacuum for approximately 6 hours, then allow the part to fully cure before demolding.
- Remove the peel ply and trim the part to the desired size.

The panels were cut using a scroll saw and joined using box joints.

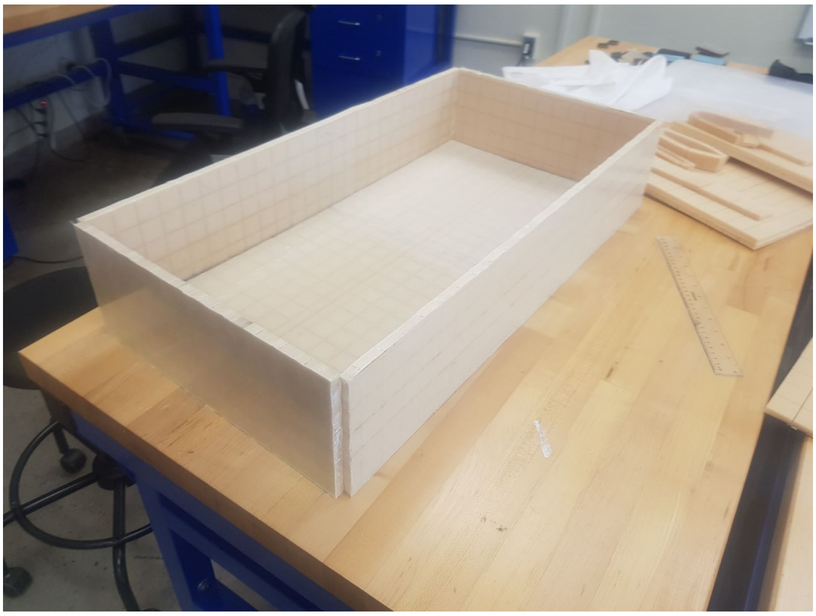

Figure 3: Battery box panels cut to size and ready to be joined

To bond the joints, epoxy resin was mixed with fumed silica to create a thick, peanut butter like adhesive.

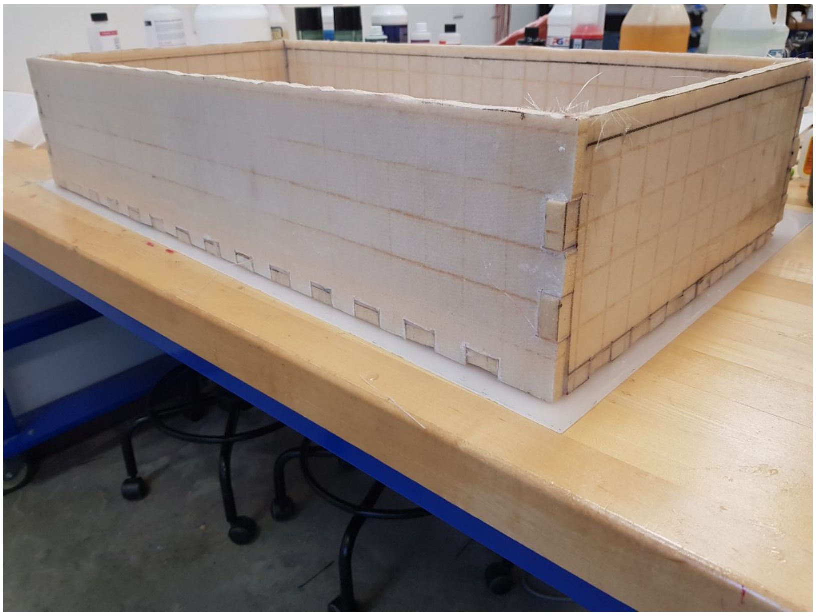

Figure 4: Epoxy bonding of battery box joints

An industry standard adhesive such as DP460 could also be used, but cost constraints made this option impractical.

3.2 Aeroshell

The aeroshell represents the most geometrically complex composite component of the solar car. While it is not intended to be structural, its aerodynamic performance depends heavily on surface quality and geometric accuracy. During the summer, small scale prototypes were used to explore feasible manufacturing methods while minimizing time and material costs.

3.2.1 Manufacturing Process

Making the Mold

Figure 5: 3D printed pattern coated with epoxy coating

Composite fabrication begins with a pattern, also known as a plug or male mold. The pattern must closely match the final desired geometry. For this project, a small canopy shape was 3D printed in multiple parts and joined together using Gorilla Glue with PLA. Because raw 3D prints have a rough surface finish, the assembled part was coated with epoxy coating resin, wet sanded progressively up to 1500 grit, and polished using a polishing compound to prepare it for mold making.

Figure 6: 3D printed pattern prepared for mold making

Next, the female (negative) mold is made. The reason a female mold is required is that the surface against the mold becomes the outer surface of the part, which needs to be smooth for aerodynamics. A female mold can be made in many ways; we chose to use tooling gelcoat with fiberglass strand chop mat and polyester resin. This was done by applying at least two layers of gelcoat onto the pattern and then laying enough layers of fiberglass strand chop mat, starting with thin plies until the mold became sufficiently thick.

Figure 7: Tooling gelcoat applied to the plug

Tip: Apply tooling gelcoat liberally; it should not be brushed on like paint. Instead, build it up until it reaches a couple of millimeters in thickness.

Figure 8: Female mold fabrication using gelcoat and fiberglass

The final step is demolding. Some difficulty was encountered during this process, as the plug adhered to the tooling gelcoat at the edges, even after smoothing the 3D print. This was likely due to the edges not being smoothed as carefully as the main surfaces. As a result, a small amount of force was required to successfully demold the part.

Figure 9: Demolding the female mold from the plug

After demolding, we noticed that an insufficient amount of tooling gelcoat had been applied, resulting in thin areas in some regions. A thin additional layer of tooling gelcoat was applied to correct this.

Figure 10: Female mold coated with tooling gelcoat after demolding

This approach has some drawbacks, as the surface finish is not as smooth. However, since this was a small scale prototype, it was acceptable for our purposes. For future layups, applying a greater amount of tooling gelcoat is recommended.

Making the Part

After curing, the composite aeroshell was fabricated inside the mold using the same wet lay up and vacuum bagging techniques used for the battery box panels.

Figure 11: Small Scale Aeroshell Canopy lay up inside the female mold

After layup, it was vacuum bagged and demolded.

Figure 12: Vacuum bagging

Figure 13: Final composite aeroshell prototype

This method provides a scalable and repeatable approach for manufacturing an aeroshell once a high-quality pattern is available.

3.3 Testing and Simulations

Testing is essential when designing structural composite components. While the aeroshell is non structural, the battery box required validation through mechanical testing. Both physical testing and preliminary simulations were explored.

3.3.1 Mechanical Testing

Initial testing focused on sandwich structures using fiberglass and carbon fiber face sheets with a 3/8-inch-thick Divinycell H60 core. Compression and flexural tests were conducted following ASTM C365 and ASTM C393 standards.

Tests were conducted using the Universal Testing Machine (Instron), and raw data, as well as graphs, were exported and analyzed in Excel. The dimensions of the compressive test were roughly 25.4 mm wide, 25.4 mm long, and 10.4 mm thick.

	A	B	C	D
1	Compressive Modulus (MPa)	~Yield Strength (MPa)	Ultimate Compressive Stress (MPa)	% Compression
2	45.2	0.74	1.82	54.1
3	55.9	1.09	1.13	26.7
4	47.6	0.79	1.92	53.2
5	47.1	0.794	0.967	26.7
6	55	0.875	1.84	53.2
7	48.8	0.845	0.976	26.7
8	49.2	0.775	81.4	90.5
9	49.8	0.844	Average	
10	4.06	0.117	Standard deviation	
11	8.15	13.9	Coefficient of Variation	
12				

Figure 14: Carbon Fiber Compressive Test Results

Compressive Modulus (MPa)	~Yield Strength (MPa)	Ultimate Compressive Stress (MPa)	% Compression
27.33	0.86	0.86	28.9
28.86	0.74	1.27	57
28.7	0.71	0.856	28.88
34.2	0.68	1.23	57.7
39.85	0.75	1.84	94.6
31.8	0.748	Average	
5.22	0.068	Standard deviation	
16.41	9.1	Coefficient of Variation	

Figure 15: Fiberglass Compressive Test Results

Results Table 1			
	Modulus (Automatic)	Flexure stress at Yield (Zero slope)	Load at Yield (Zero slope)
	(MPa)	(MPa)	(N)
1	4,709.74	22.07538	619.47351
3	4,835.84	21.00264	596.38873
5	5,575.24	20.5684	557.89624
Mean	5,040.27	21.22	591.25
Standard d	467.57	0.78	31.11
Coefficien	9.28	3.66	5.26

Figure 16: Carbon Fiber Flexural Test Results

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Figure 17: Fiberglass Flexural Test Results

It is evident from these graphs that carbon fiber outperforms fiberglass in terms of strength-to-weight ratio, as the specimens had roughly the same weight. The flexural stress-strain curve below makes it even clearer to see. However, fiberglass was chosen for the battery box because carbon fiber is electrically conductive, and using it would pose a risk in that application.

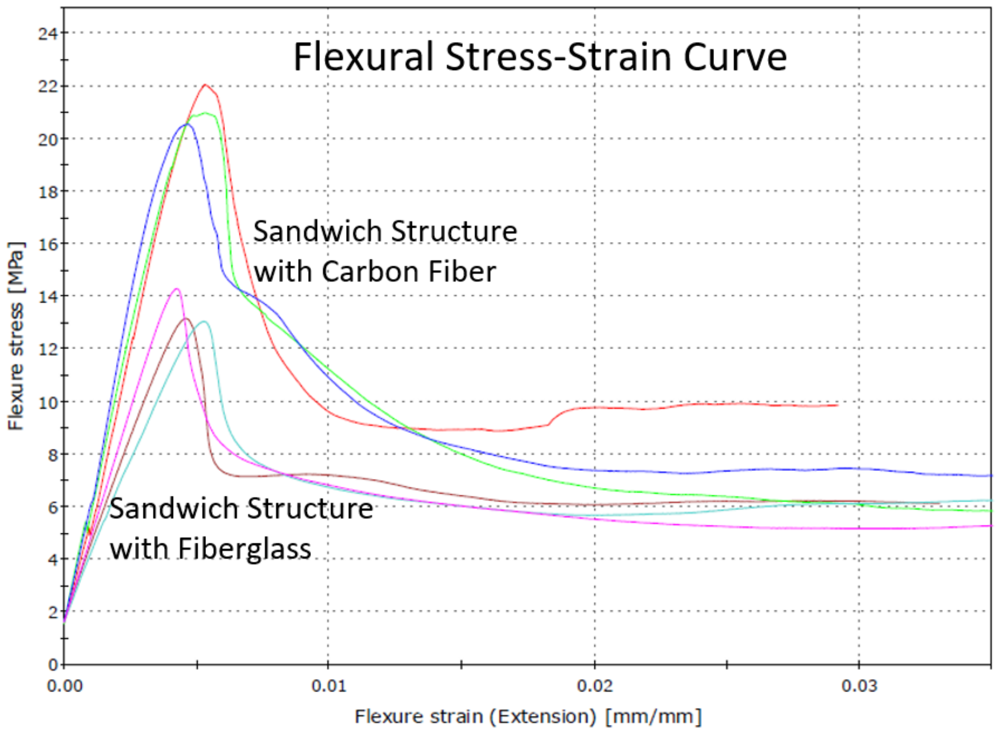

Figure 18: Felxural Stress-Strain Curve

3.3.2 Simulations

Finite element analysis was explored using ANSYS ACP and ANSYS Mechanical. The original plan was to replicate experimental tests in simulation and validate material properties before extending the analysis to the full battery box. Due to time constraints and the relatively low structural demands, manufacturing proceeded using experimental data alone. However, a preliminary composite layup and flexural simulation were successfully created.

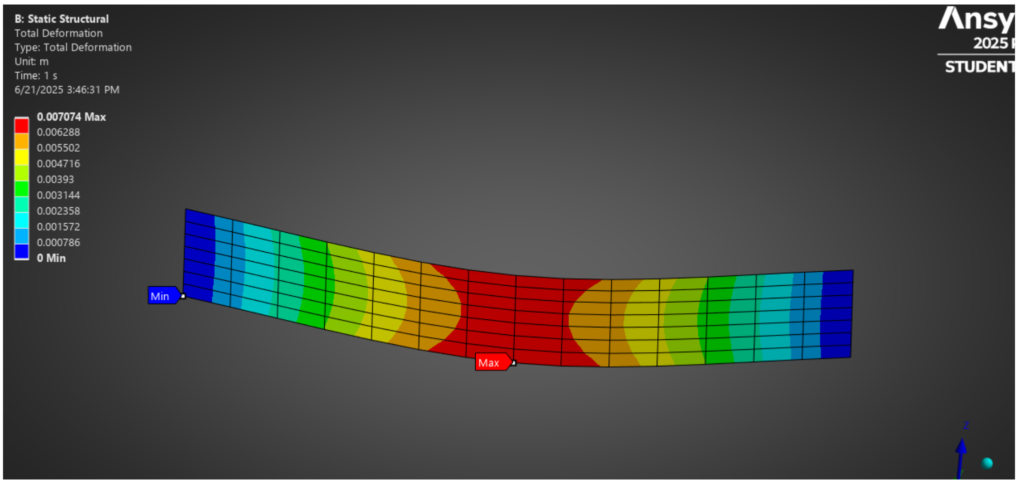

Figure 19: Preliminary composite simulation in ANSYS

4 Conclusion

This project established a foundation in composite materials through hands on fabrication, testing, and preliminary simulation work. A functional battery box was designed and manufactured, and a scalable aeroshell manufacturing process was developed. Mechanical testing provided confidence in design decisions, while simulation work laid the groundwork for future improvements. Overall, the work demonstrates that composite materials can be effectively used in solar car applications when approached with careful fabrication, testing, and iterative learning.

Appendix

Below are pictures showing some failures and some successes that were not directly relevant or helpful to the report.

Figure 20: Failed attempt to direclty use 3D print as female mold

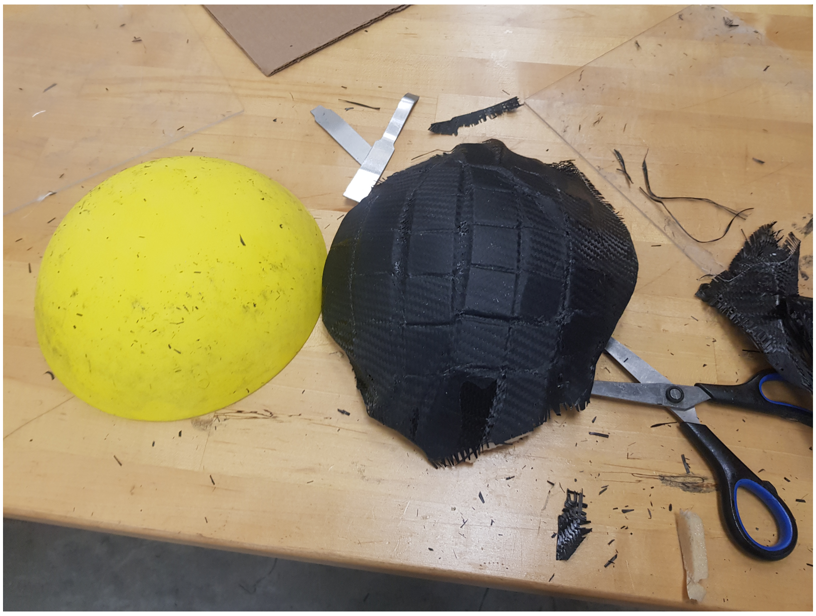

Figure 21: Another failed attempt but better

Figure 22: Flexural Test Set up