Characterizing and Optimizing Hemp Composite

Team ShakeWeight

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Abstract

The purposes of this project were to

1) develop a manufacturing process for hemp composites,
2) characterize the manufactured composites via testing,
3) determine if the hemp composite is comparable to other common composites such as fiberglass and carbon fiber.

A Standard Operating Procedure was developed and made safer by performing HAZOP and FMEA analysis. The samples were cut with a laser cutter into desired shapes for testing, and a variety of tests were performed to characterize the material. From that characterization, it was determined that the hemp composites are a comparable alternative to both fiberglass and carbon fiber composites. This is an important finding because it supports hemp composites as a sustainable, inexpensive alternative to more widely used materials.

Background

Hemp has been cultivated and used for thousands of years. It is lightweight and strong, while also being cheap and easy to grow, making it viable for many different uses. Due to hemp's association with marijuana, and the emergence/quick integration of inexpensive polymers, hemp's usage drastically decreased. Recent deregulation is allowing the hemp industry to grow once again. Exploring the viability for competitive hemp composites, the fundamentals dictating characterization of the composites include:

- Fick's Laws of Diffusion
- Young's Modulus of Elasticity
- Catalytic Chemistry

Hypotheses

The goals for this project, outlined in the abstract above, laid the framework for specific hypotheses that guided research. These hypotheses are listed below:

- A pneumatic compression method will create stronger composites with fewer impurities and a lower epoxy to hemp ratio
- The material and manufacturing costs associated with hemp composites will be lower than current fiberglass/carbon fiber composites
- The strength of hemp composites made in lab will be comparable to that of fiberglass and carbon fiber composites

The following results will show the endstate of these hypotheses after a variety of tests and analysis done on lab made hemp composite samples.

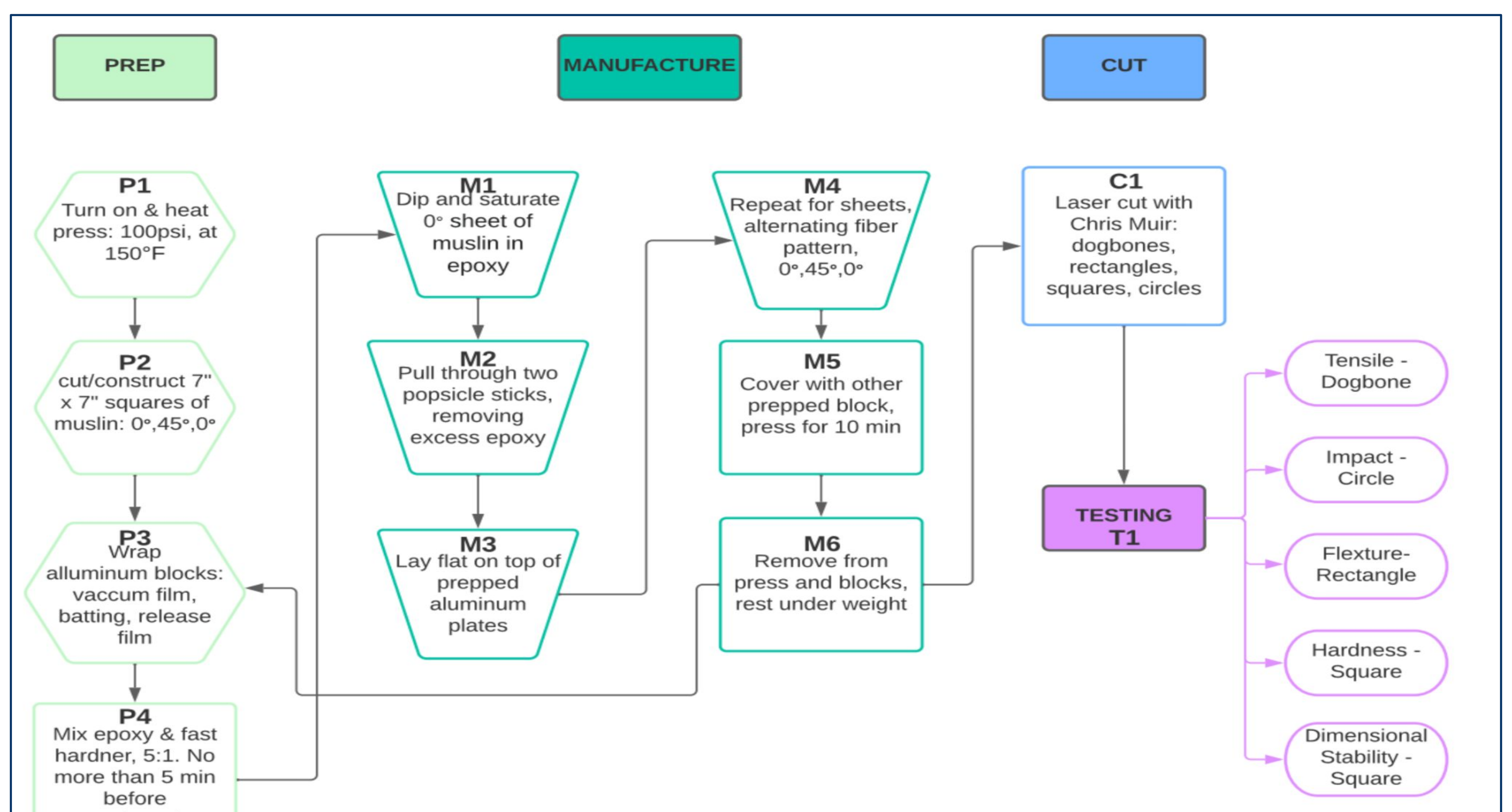


Figure 1. Process Flow Diagram

Methods

Primary areas of exploration included:

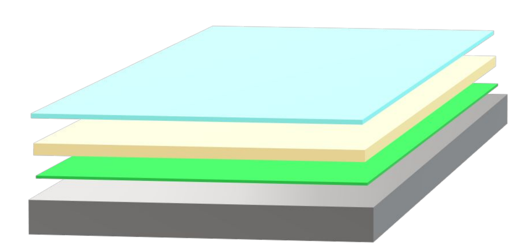
1) Vacuum bagging (previous group's method) vs heated press (current method)
2) Variations in pressing conditions - temperature, block finish, presence of additional wicking epoxy material
3) Variations in layup and fiber treatment - number of layers and their orientation, presence of moisture and its effects on composite characteristics.

Mechanical tests included:

- Tensile
- 3-point flexure
- Impact
- Hardness
- Surface Energy
- Water Absorption

Current methods:

- Utilizing the morgan press heated to 150 °F , run at 100 psi pressure, and two 8" x 8" polished aluminum blocks
- Aluminum blocks layered from inner to outermost layers:



- ➢ Porous release film
- ➢ Wicking batting material
- ➢ Impermeable block lining film
- ➢ Polished and waxed aluminum block

- Woven hemp muslin are dipped and saturated in a mixture of West System 105 thermally curing resin and 205 fast hardener
- Sheets are pulled through a narrow gap, removing excess epoxy resin but still leaving sheets fully saturated
- Sheets are layered in a 0°, 45°, 0° pattern, where the layer differentiation comes from the weave orientation relative to the square shape of the layer
- Second aluminum block is placed on top and sample is pressed for 10 min
- Laser cut samples after at least 4 days of curing

Results

- Compression with the heated press led to samples having higher tensile strength than the vacuum bagging samples. This was established early in the experiment. The added benefits of a smoother finish, lack of air bubbles, and a lower resin to fiber ratio were other contributing factors in choosing the compression method.

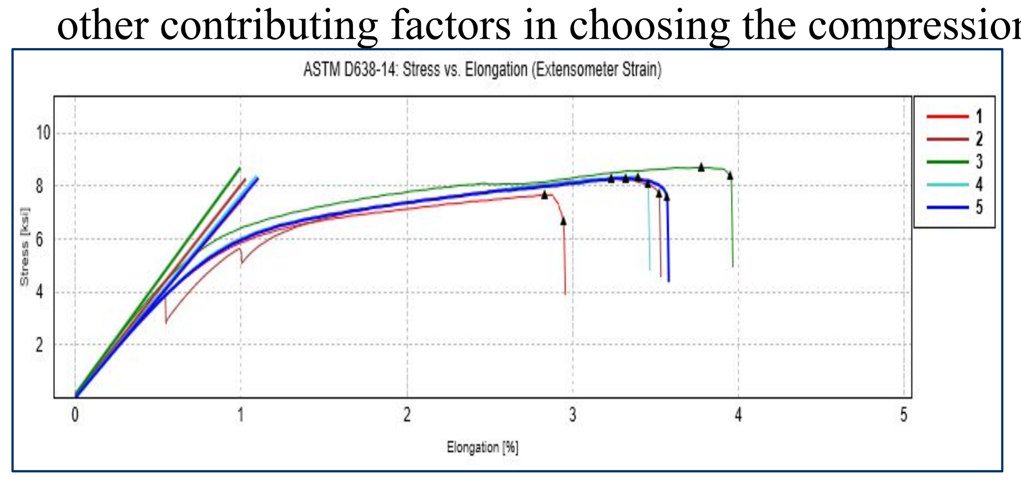


Figure 2: Results from tensile tests for a 5 layer sample. Average tensile strength: 8.27 ksi (+/- .37)

Tensile Strength Table 1	
Compression	8.17 ksi
Vacuum	7.82 ksi

Table 1: A comparison of the average tensile strength for compression vs vacuum bagging. This is a collection of all sample data

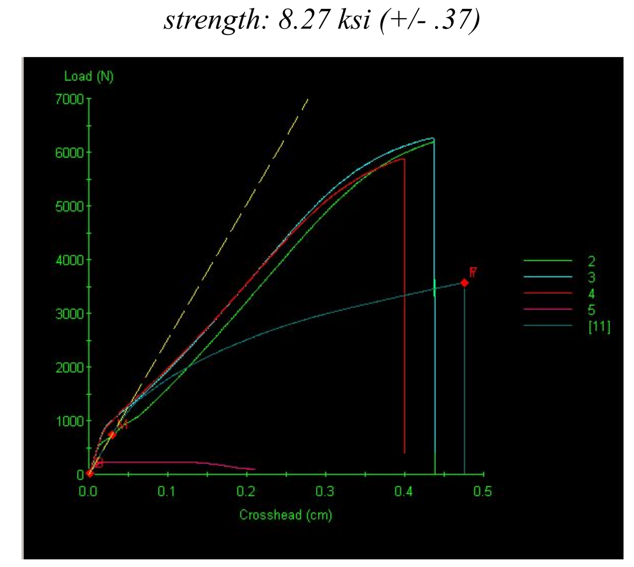


Figure 3: Flexural data for a 5 layer sample. Average peak stress: 52.2 ksi

Flexural Peak Stress Table 2	
Compression	21.5 lbf
Vacuum	15.4 lbf

Table 2: A comparison of the average flexural peak load between compression and results from a vacuum bagging sample

Results (cont.)

- Absorption is dependent on the cure time and the block preparation.

Cure Time	Weight % Increase
~3 weeks	+7.4%
~4 days	+21%

Table 3: Cure time and wt % increase of two square, 5-layer sample prepared with batting

Block Prep	Weight % Increase
Wax Paper	+15.8%
Batting	+7.4%

Table 4: Block prep and wt % increase of square, 5-layer samples, cured for ~3 weeks

- High moisture content in the fibers is detrimental to this specific fiber-resin matrix. The exothermic epoxy hardening process reaches temperature above water's boiling point, causing water to evaporate and introduce bubbles to the composite.

Polyacrylonitrile (PAN) ~90% of the CF industry	~$5 - $9.75 per pound, ~80 ksi tensile strength
Pitch-based ~10% of CF industry	tensile strength of 108 ksi and 363 ksi, ~$15 per pound
Fiberglass A-glass (alkali), extruded	$2 - $3 per pound, tensile strength ~13.5 ksi
Hemp Bast Fiber, most valuable portion of the plant for fiber	**$0.13 per pound, tensile strength dependent on fiber diameter, @ 66μm ~36 ksi**

Table 5: Cost and tensile comparison for hemp, fiberglass and carbon fiber

Discussion

Results from early on in this project showed that the heated press method created samples with higher tensile and flexural strength than the vacuum bagging method. The heated press applies far more pressure to the sample than vacuum bagging, reducing textural inconsistencies and air bubbles as well as lowering the resin to fiber ratio. Areas for future exploration include: 1. Additional pretreatment of hemp 2. Fiber-epoxy chemical bonding instead of mechanical 3. Biodegradable epoxies 4. Scaling up outside of the 8" x 8" heated press

Comparisons of hemp and fiberglass show promising results for hemp composites. Hemp fibers are able to endure higher tensile loads based on fiber diameters and are also cheaper by a factor greater than 20 in some cases. Although polyacrylonitrile and pitch-based carbon fiber perform better than hemp in tensile strength, the cost difference is even more pronounced. Overall, results suggest that hemp composites can perform as well as fiberglass while being significantly cheaper to produce. Although carbon fiber may be stronger than hemp, future research could further optimize hemp composites and make it a more competitive, sustainable alternative.

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