6/5/2026

Lightweight Composite Repair System

Ryan Hong, Kai Tom, Max Cote, Alex Dixon, Dylan Stevenson, Eli Tachovsky

Mentors: Xiaoxi Wang, Mohamed Azdamou, John Lin, Navid Zobeiry, Kendall Johnson, Alex Gray, Luna Huang,Glory Edwards, Pradeep Krishnaswamy, Kirsten Bossenbroek Spalding, and John Spalding

Materials Science and Engineering & Mechanical Engineering

Introduction

- **Industry Shift:** Modern aviation is moving toward a heavy reliance on composite materials
- **Current Repair Bottleneck:** Producing quality repair parts is labor and energy intensive, sometimes requiring large scale equipment such as autoclaves
- **Innovation:** Development of a universal, out of autoclave repair system design for localized applications
- **Key Technology:** Utilizes lightweight expandable materials and localized heating
- **Result:** Achieves autoclave-quality quality and performance

Problem Statement

- **Project Context:** Multi-year project, building upon previous years research and development
- **Primary Objective:** Design, fabricate and validate a portable lightweight composite repair system
- **Performance Requirements:**
  - **Pressure Generation:** Capable of maintaining 90 psi using expandable foam
  - **Thermal/Duration Requirements:** Sustains a constain 350 °F during cure
- **Engineering Constraints:**
  - **Out of Autoclave (OOA):** Must perform repair without external pressure vessels
  - **Structural:** Requires managing high reaction loads with limited mounting options

Component Selection

- **Enclosure:** NOMEX Fabric & Wire Mesh
- **Cables:** Galvanized Steel
- **Foam:** Expandable Foam
- **Heating Element:** Heat Blanket Controlled with Heatcon Controller and Hot Plate
- **Filler Material:** Silicon Intensifier
- **Pressure Measurement:** FujiFilm LLW Hi-Temp

2024

Repair Housing Apparatus

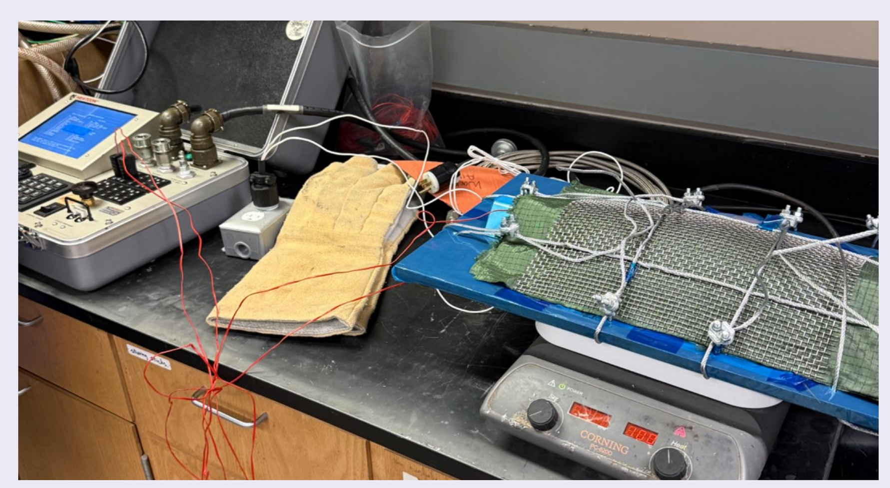
Design and test a rigid housing apparatus that is capable of withstanding at least 100 psi at 350°F for at least an hour.

2025

Fabricate Expandable foam

Refine expandable foam medium that expands and resists deformation under pressure to test with a mockup flat CFRP Plate

2026



Lightweight Repair Apparatus

Design *lightweight* repair system using expandable medium and flexible cover and test on a mockup CFRP hat stringer

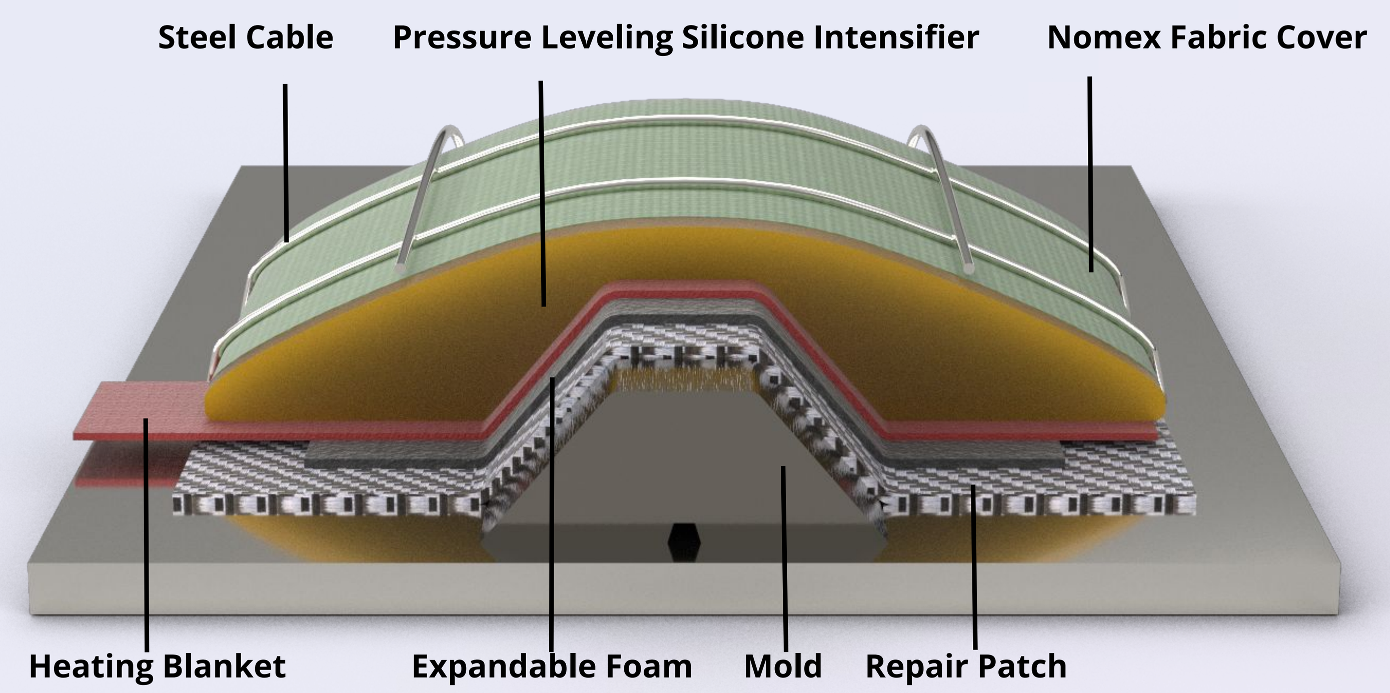
Design

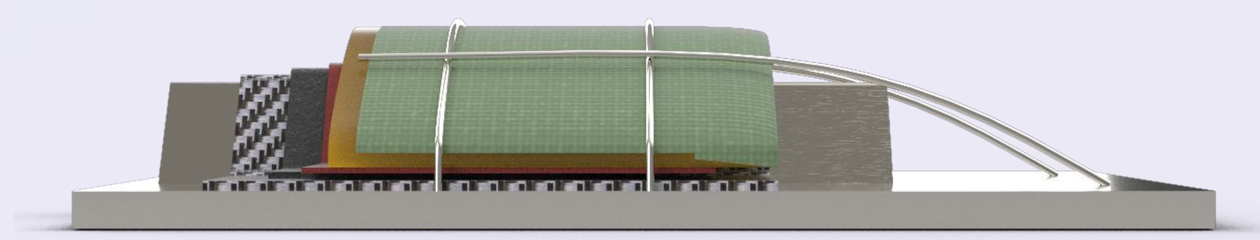
Mounting Solution

- **Problem:** Generate reaction force caused by expandable medium without further damaging carbon fiber
- **Solution:** Steel cable shares load in tandem with Nomex fabric distributing reaction forces into switchable magnets

Expandable Medium Solution

- **Problem:** Generate pressure and heat to cure autoclave specified CFRP parts for repairs
- **Solution:** Use proved expandable foam in tandem with silicon intensifier as a pressure leveling system



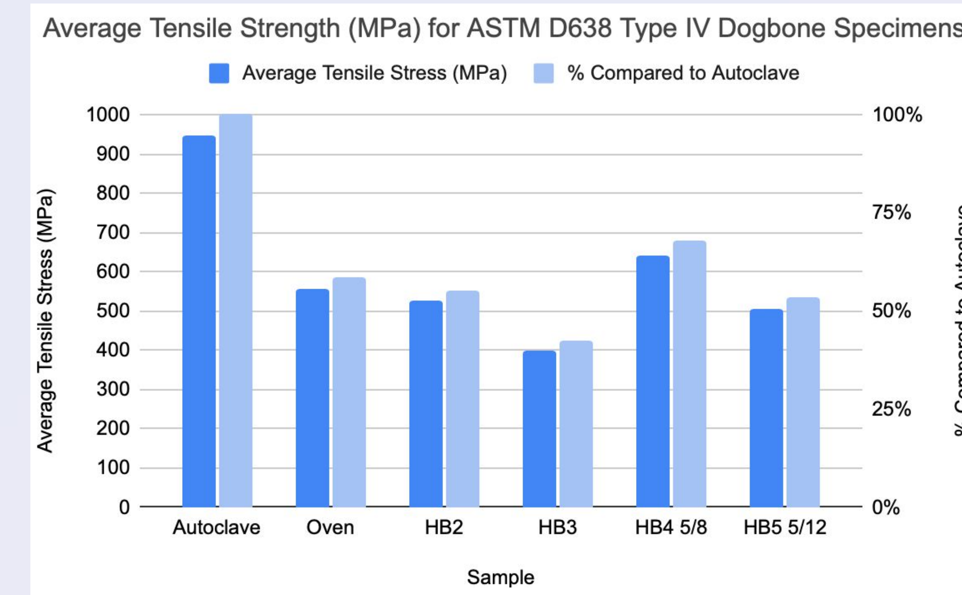


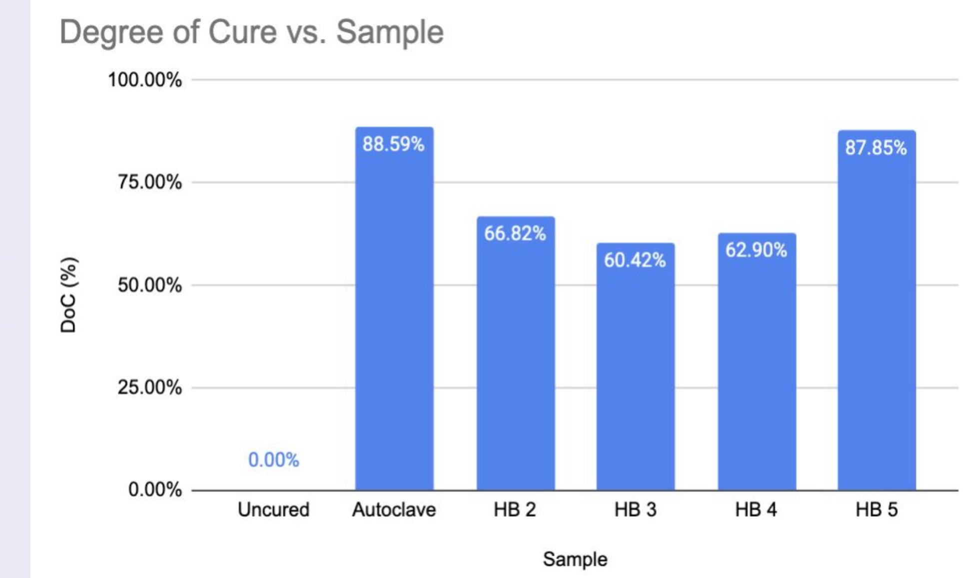
Testing

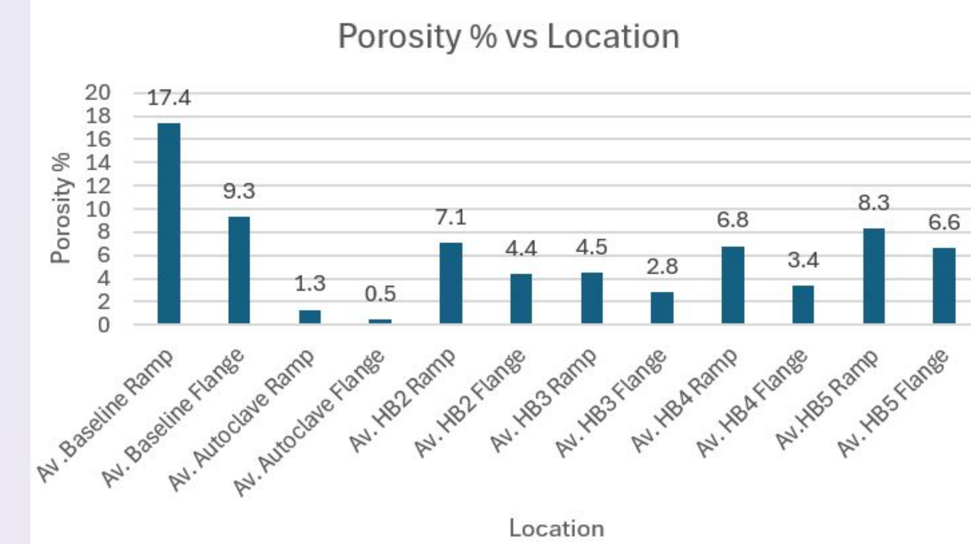
Differential Scanning Calorimetry: Degree of Cure
Tensile: Ultimate Tensile Strength
Microscopy: Porosity/Void %

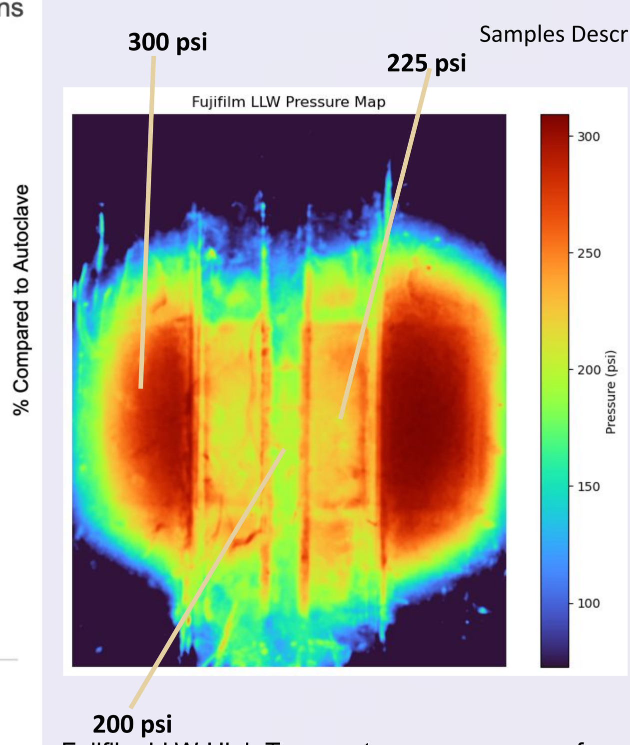
*Samples for DSC are average of flange and ramp, tensile samples taken from flange

Sample	Description
Autoclave	Standard Vacuum Bag
Oven	Clay with No Debulks
HB2	Clay with No Debulks
HB3	Clay + Intensifier with No Debulk
HB4	Only Intensifier with 4 Debulks
HB5	Only Intensifier with 5 Debulks







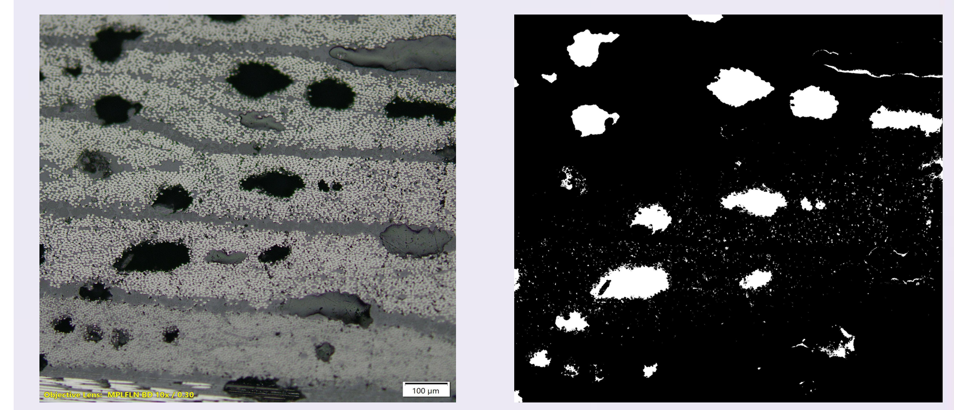


Fujifilm LLW-High Temperature pressure map from HB5 (bar)

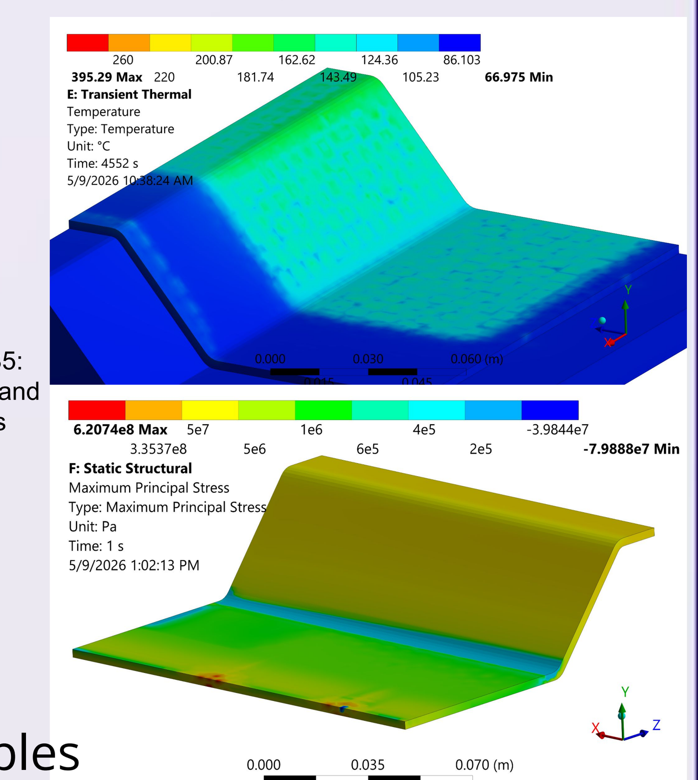
Samples Descriptions

Tenon Refractory Mortar

EZ Composites Silicone Intensifier



Raw microscopy (left) Processed image (right) Images are of HB5 Ramp



Simulations of HB5: Temperature (Top) and Maximum Stress (Bottom)

Summary

Optimal Results

- Optimal Outcomes: HB4 achieved highest tensile strength, HB5 highest cure degree, and HB3 lowest porosity.

Reasoning

- HB5: Minimized thermal lag between top and bottom thermocouples
- HB5: Excessive pressure triggered resin leakage and micro-matrix cracking

Pressure Map

- HB5: Maximum pressure: ≈ 300 psi. Minimum pressure ≈ 40 psi
- HB5: Severe pressure drop in the high curvature region between flange and ramp

FEA

- Simulated maximum principal stress corroborates lack of pressure at flange to wall interface and concave corners while convex corners correspond to higher pressures
- Thermal simulation provides temperature gradients in repair region and equivalent thermal mapping for heat blanket effectiveness