MANUFACTURING A FUSELAGE

ILLINOIS

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HOW NOT TO MANUFACTURE A FUSELAGE

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Overview

1 Design Rationale

2 Manufacturing Plan

3 What Went Wrong

4 Why Did It Go Wrong

5 What Could Have Been Better

DESIGN RATIONALE

FUSELAGE DESIGN REQUIREMENTS

- Base Design Requirements was provided by the SAMPE Fuselage Regulations
  - Minimum Length: **24 Inches**
  - Maximum Inner Diameter: **5.5 Inches**
  - Maximum Outer Diameter: **6 Inches**
  - Minimum of 4 Cutouts, 2 on Left, 2 on Right
    - Cutouts must be **at least 2 inches in Diameter**
    - **Minimum 5 inches away** from the edge of the Fuselage and **15 inches apart**

Effective Thickness to Play With: 0.5 inches

- Fiber Glass only Approved Material and Kevlar/NOMEX for Core
- Resin Systems - “Open Ended”
- Side view design of the fuselage

PRELIMINARY DESIGN APPROACH

- Main Design Objective: **Minimize Deflection**
  - **Comparison study** with multiple Material options
  - **Develop and Optimize Ply Orientation** – Further increase strength and reduce deflection
- Ply Orientation technique
  - Simplest Idea – Symmetric layup entirely of composite plies
  - A **Core** is required for saving weight while maintaining structural integrity
  - **Composite Laminate Theory** – Simple and Ideal method for calculating the ABD matrix with multiple ply stackup.
  - **Composipy** was used for ABD Matrix computation.
  - Modifications were incorporated from [1] to adapt the CLT to a hollow cylinder geometry.

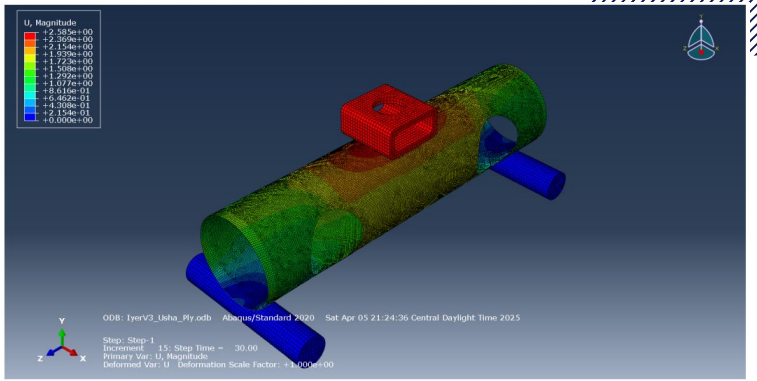


Figure 1: Maximum Displacement for the Ply Orientation [-45/0/45/90/Core/90/45/0/-45]

MATERIALS AND MANUFACTURING

Material Selection: E-Glass Prepreg and NOMEX Honeycomb

- **Composite System** – *Woven 7781 E-Glass/Epoxy Prepreg*
  - Plain-Weave, and Black Pigment added.
  - Tensile modulus ≈ 10.5 msi, strength ≈ 285 ksi → meets SAMPE stiffness target at lower cost than S-Glass despite inferior properties
- **Core** – *NOMEX® Honeycomb*
  - Excellent shear/compressive strength-to-weight, inherent flame resistance
  - Chosen over Kevlar for moderate-load cabin sections to reduce budget without sacrificing safety

Manufacturing: Vacuum Bagging with Autoclave

- Provides ideal balance between Cost and Quality, and is relatively easy to implement.
- **Availability:** The lab already has a full vacuum setup and an autoclave capable of 60–85 psi.
- **Process Control:** Prepreg lay-up under vacuum eliminates infusion-flow variables, reducing chances of leaks, dry spots, and resin-rich zones—key for first-time build success.

PLANNED PROCESS WORKFLOW

Inner Shell & Core Prep

- **Component Preparations**: Measure and cut **20 plies** of 7781 E-glass prepreg (18”×26”). Pre-cut peel-ply, breather, and bag film; allow plies to thaw overnight for full tack.

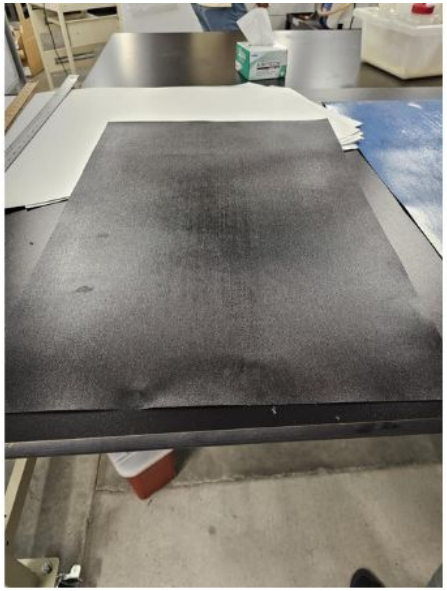
- **Mandrel Preparation**: Prepared in the following sequence:
    - Acetone wipe > Chemical Release Agent > Scribe 0° Reference lines
    - Wrap Vacuum Bag, Breather Ply, and Peel Ply on top of the Mandrel. Adhere to surface using Tape

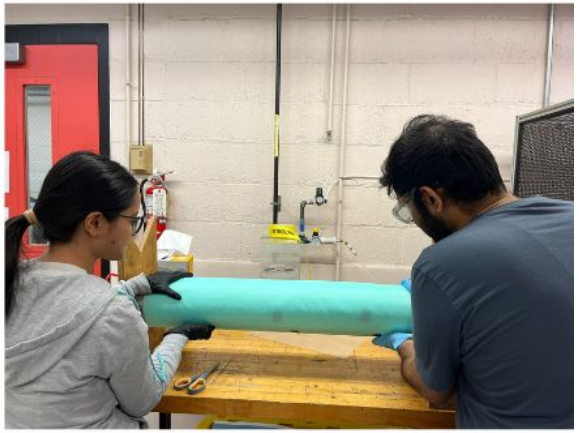
- **Inner-Shell Lay-Up** : Stack a **14-ply blanket**, then wrap around the mandrel in one smooth pass. Debulk every 4–6 plies; ensure a wrinkle-free surface.
- **Core bond setup** : Apply a thin epoxy adhesive film on the prepreg surface. Align **Nomex® honeycomb** and adhere it onto the prepreg. Leave the assembly to cure at room temperature for 6-7 hours.
- **Outer-Shell Lay-Up:** Stack a **6-ply blanket**. Apply adhesive epoxy on one of the prepregs and then wrap around the mandrel in one smooth pass.

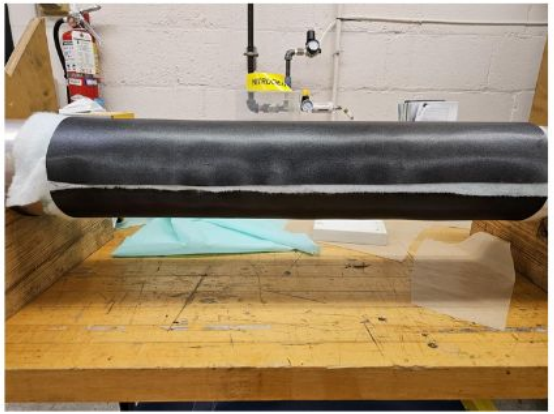
PLANNED PROCESS WORKFLOW

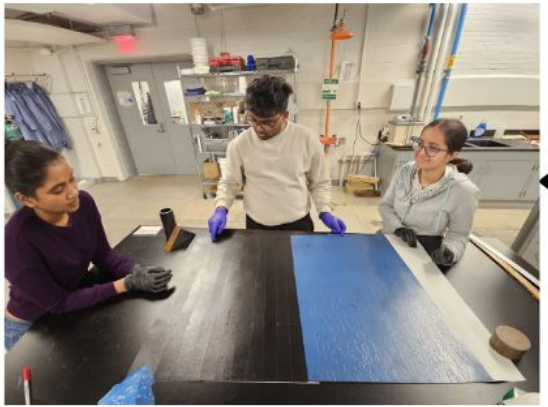
Bagging & Curing

- **Bagging the Mold** : Lay down peel-ply, breather (full wrap), and vacuum bag. Seal with a double bead of tape and add silicone mastic at corners and the vacuum port.
- **Leak check & consolidation** : Pull vacuum to ~28 in Hg and hold for 15 minutes, accepting only if pressure loss ≤ 1 in Hg. Address any leaks and re-test until stable.
- **Single-step autoclave cure** : Cure at 275 °F (135 °C) and 40 psi for 90 minutes, followed by a controlled cool at 2 °C min^{-1}, co-curing the inner skin, core, and outer skin into a single, void-free laminate.







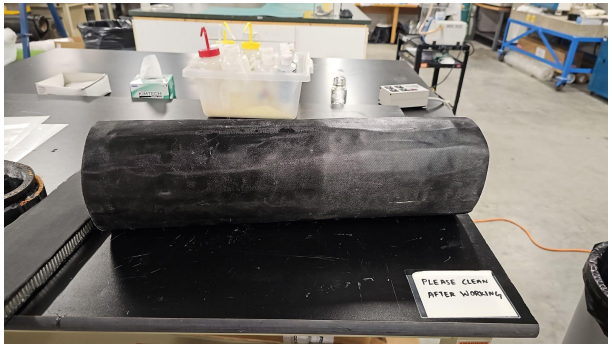








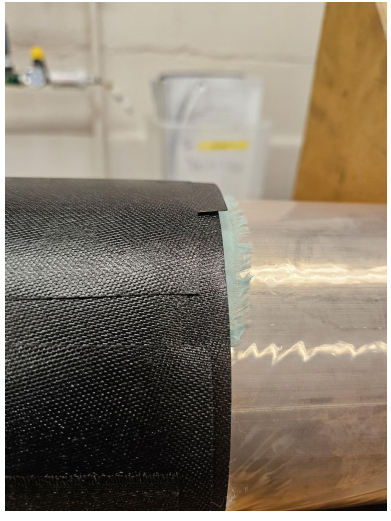



PLEASE CLEAN
AFTER WORKING

WHAT WENT WRONG

WHAT WENT WRONG

- **Mandrel was too heavy and difficult to handle –** High Wall Thickness; No Proper Fixture
- **The prepreg sometimes refused to adhere properly, increasing the potential for voids –** Resin was still cold, and thus lacked tackiness
- **Underestimating the length of Composite during preliminary calculations and cutting –** While we did account for overage, the increase in diameter dimension due to the peel ply and specifically the breather cloth proved too much
- **Plies on the lower part of the mandrel may have not adhered well –** The tension on the ply while wrapping could have been too low, Gravity could have well played a role
- **Potential for increased Stress Concentration Zones due to Stacking –** Provides an increased number of edges where a crack may initiate propagation
- **There needs to be a better methodology for attaching the core to the prepreg through adhesive epoxy**
- **Excessive Wrinkling over the Composite once air was evacuated –** Ply Slippage, Buckling



WHAT COULD HAVE BEEN DONE BETTER

Materials & Tooling

What Went Wrong	Mitigation Measures
Prepreg sheets lacked tack	Warm plies in 25 °C cabinet until ≥ 20 °C (IR gun check) Keep lay-up room ≤ 60 % RH, desiccant in storage bags
Mandrel was too heavy	Replace with thin-wall shell or add cradle with bearings

Lay-up & Stacking

What Went Wrong	Mitigation Measures
14-ply blanket amplified wrinkling	Split into two 7-ply wraps; light tack-spray every 5 plies; roller debulk each quarter-turn
Diameter overage mis-estimated → bridging	Update diameter calc with real consumable thickness; switch to low-loft breather around seams
Bottom plies sagged & didn't stick	Warm lay-up table; out-time log; apply temporary shrink tape under mandrel during wrap

Lay-up & Stacking

What Went Wrong	Mitigation Measures
Use of Epoxy for Core -Prepreg Adhesion	Use of “GOOD” face sheets as adhesion between core and prepreg layup would have been easier to handle than using EPOXY as an Adhesive.
Wrinkling Over Composite when vacuum bagged	Use of Heat Shrink tape to ensure proper layup of prepregs.
Staggering of Plies- Higher stress concentration	Controlled Staggering which can be modelled to completely understand and predict the effect

THANK YOU!

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Questions?