Innovative Structural Battery Design: Leveraging MESC for Weight Reduction and Efficiency

Stanford | ENGINEERING
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Summary

This research investigates the innovative design of a battery-integrated structure using Multifunctional Energy Storage Composites (MESC). By embedding batteries within the existing structure, the design aims to achieve substantial weight reduction while ensuring structural integrity. The study details the fabrication process of MESC, evaluates the use of PCBs for wire management, and explores the use of foam for gap filling. It also considers the broader implications for future aerospace applications.

Introduction

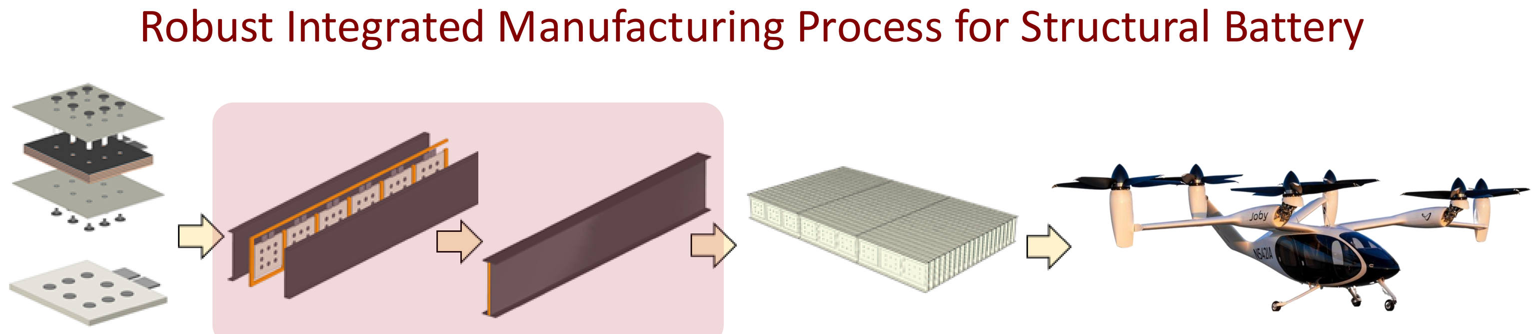
- Growing demand for lightweight and efficient energy storage solutions in aerospace due to the industry's shift toward electrification.
- Traditional battery systems, essential for electric aircraft, contribute significant weight, limiting range and overall performance.
- Reliance on traditional fuels persists due to their higher energy density compared to lithium batteries.
- The research investigates Multifunctional Energy Storage Composites (MESC) as a potential solution to integrate energy storage directly into structural components.
- MESC offers a novel approach to reducing weight in aerospace design.
- The research assesses the effectiveness of these methods in achieving weight reduction.
- The research evaluates the ease of implementation of these methods in practical aerospace applications.

Objectives

- To design a MESC structure to achieve weight reduction
- To evaluate the mechanical properties and energy efficiency of the MESC
- Develop a custom PCB to improve battery connections and enhance safety
- Explore the use of liquid foam and other substances as gap fillers for MESC to optimize structural integrity and performance
- To assess weight reductions and range extension of MESC implementation

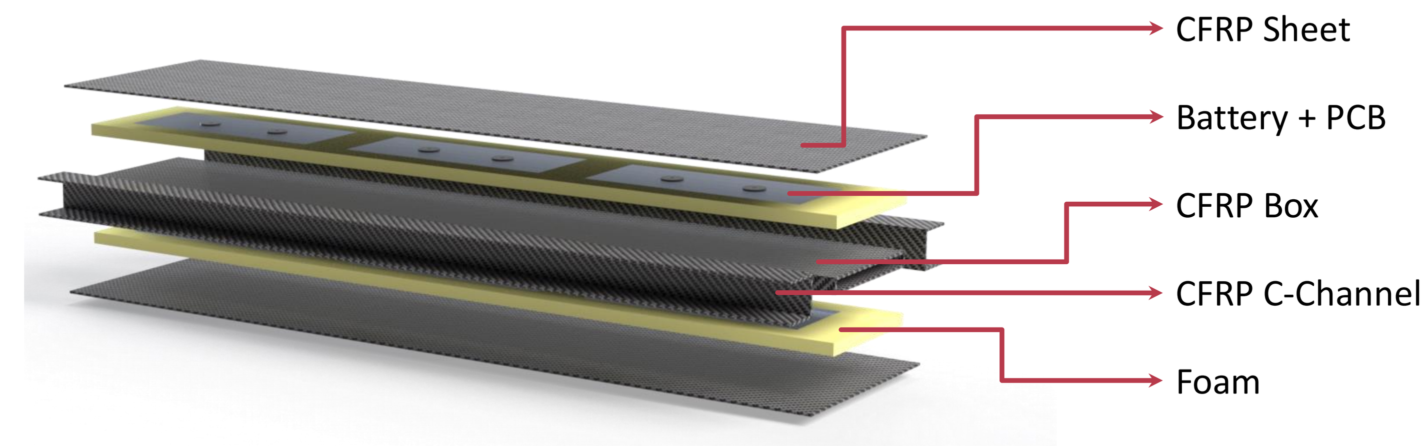
Materials and Methods

Robust Integrated Manufacturing Process for Structural Battery



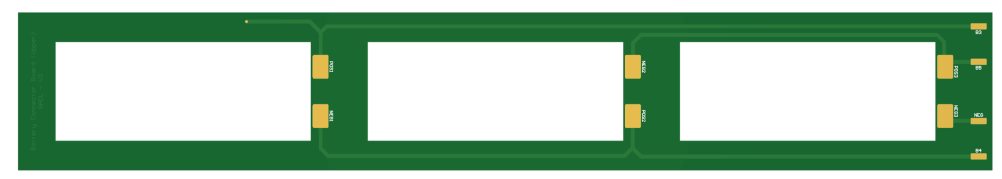
Cell Level | *Research Focus* | *Pack Level* | *System Level*

Assembly:



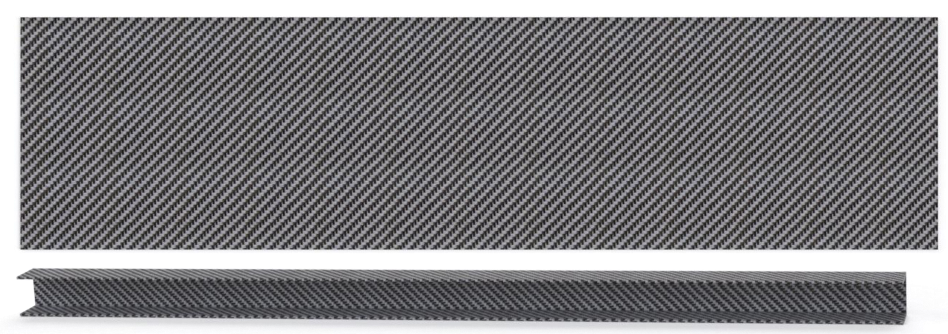
Exploded View of a Composite Battery Box Beam Assembly Featuring CFRP and Liquid Foam Reinforcement

Materials & Parts:



Printed Circuit Board (PCB)

Polyurethane Liquid Foam



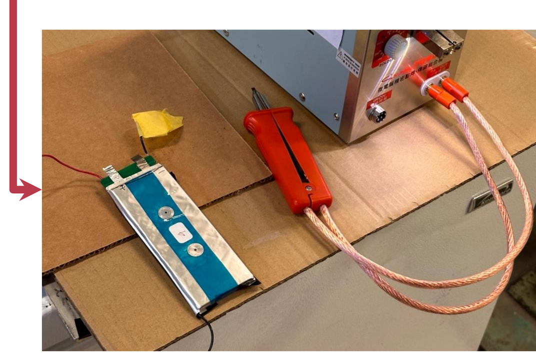
Carbon Fiber 2-Ply Sheets & C-Channel

Lithium Battery W/ Rivets

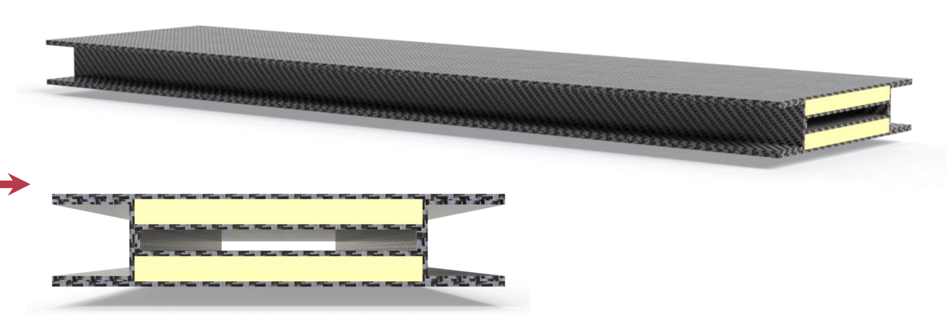
Fabrication Method:

Fabricate Carbon Fiber Components

Epoxy Battery Cells, C-Channel, and Sheet Together and Allow to Cure in a Vacuum Environment at Ambient Temperature



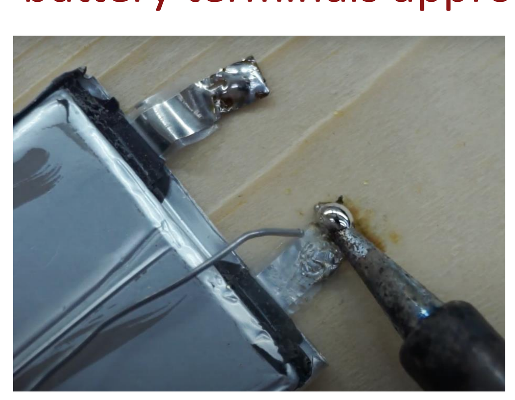
Spot Weld Battery Terminals to PCB

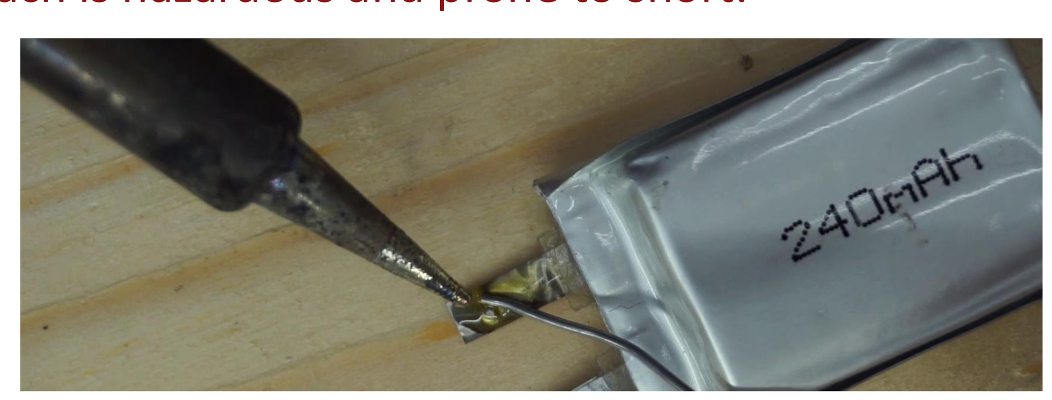


Inject Composite With Liquid Foam to Fill All Gaps & Structurally Enforce the Assembly

Discussion

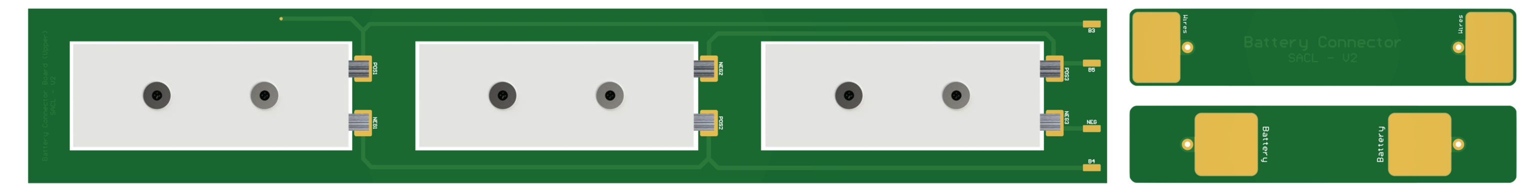
Integrating energy storage directly into the structure of an aircraft poses significant challenges. Current approach of soldering wires directly to battery terminals approach is hazardous and prone to short.





To address these issues, we explored alternative methods for connecting batteries within the composite structure. Our solution involved developing a custom Printed Circuit Board (PCB) design that is spot-welded to the battery terminals, eliminating the need for loose wires.

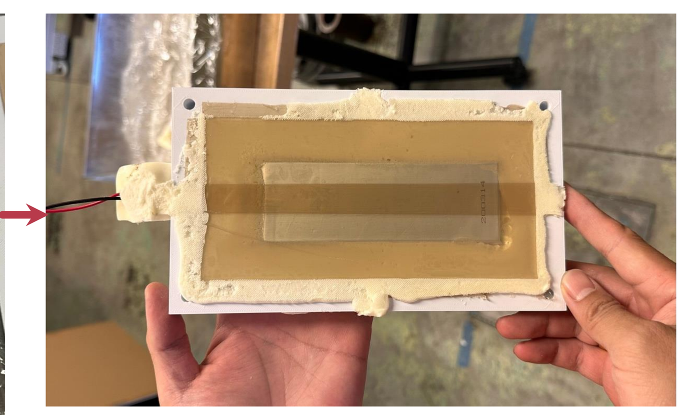
This PCB uses integrated traces for secure and reliable connections.



Another critical aspect of this research is the choice of polyurethane liquid foam for filling gaps within the MESC-integrated structure. Injecting liquid foam directly into the structure offers significant advantages over tediously manually cutting and placing foam pieces.

Polyurethane Liquid Foam Main Properties

10x	Closed - Cell	60s
Volume Expansion Before Curing	System (Low Liquid Absorption)	Cream Time (Begins to Expand)



Process of Pouring and Curing Polyurethane Liquid Foam

Results

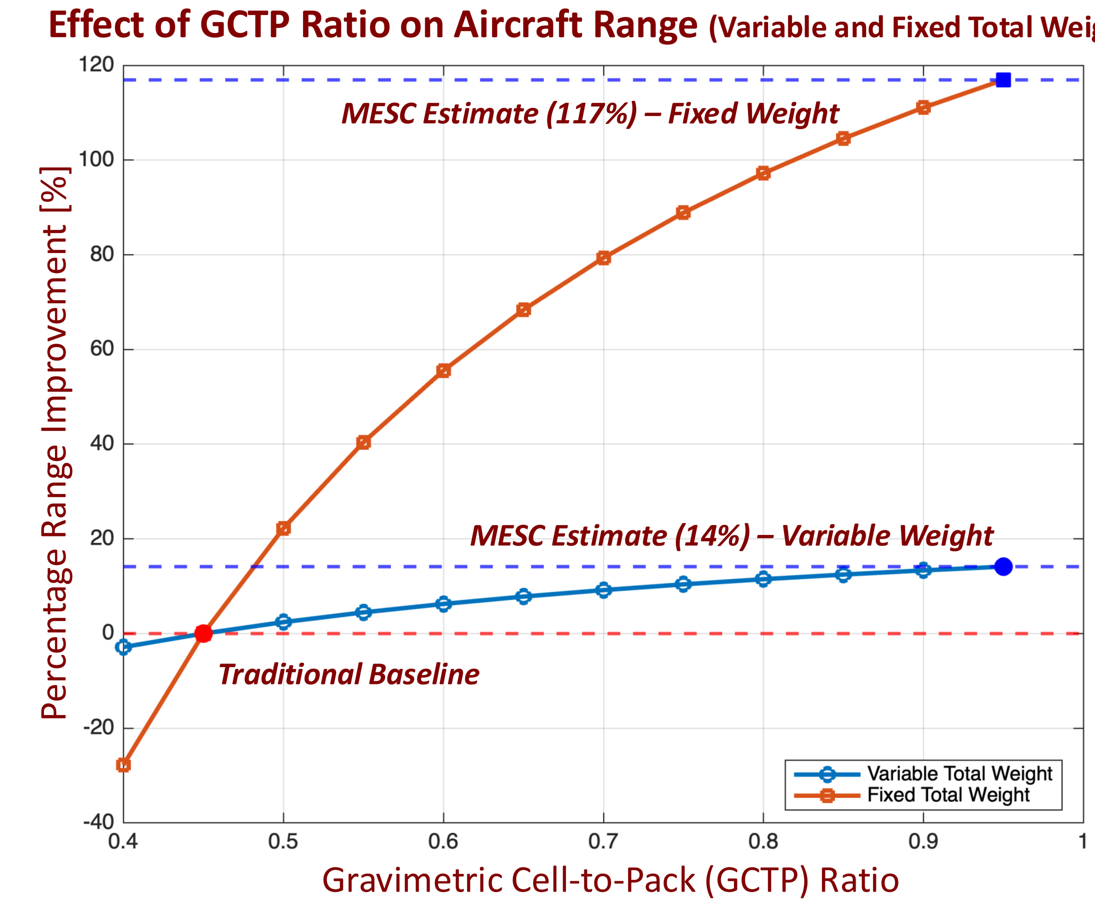
$$Range = \eta \cdot E \cdot \frac{1}{g} \cdot \frac{L}{D} \cdot \frac{W_b}{W_{total}}$$

Propulsion System Efficiency $(\eta) = 0.9$

Specific Energy $(E) = 900{,}000\ ^{J}/_{kg}$

Lift – to – Drag Ratio $(^{L}/_{D}) = 11.3$

Effect of GCTP Ratio on Aircraft Range (Variable and Fixed Total Weight)



Conclusion

This research shows that MESCs can significantly reduce weight or increase battery capacity while preserving structural integrity. By developing solutions such as a custom PCB for secure battery connections and utilizing polyurethane liquid foam for gap filling, the study addresses key challenges, simplifies the assembly process, and enhances the safety and performance of the aircraft.

Acknowledgments

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