COMPARATIVE INVESTIGATION AND DEVELOPMENT OF BATTERY ENCLOSURE FOR ELECTRIC VEHICLES

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Introduction:
The global automotive industry is rapidly shifting toward cleaner and more energy-efficient transportation, with electric vehicles (EVs) playing a major role in reducing pollution and fuel dependency. Compared to conventional vehicles, EVs are more energy efficient, environmentally friendly, and cost-effective in the long run. This shift has increased the focus on improving battery systems, charging infrastructure, and overall vehicle performance.
One of the most important parts of an EV is the battery pack and its enclosure. The enclosure acts as a protective casing for the battery, safeguarding it from impacts, vibrations, weather conditions, and accidents. It also plays a key role in maintaining proper temperature, ensuring electrical safety, and supporting the overall structure of the vehicle. Therefore, designing a strong yet lightweight enclosure is essential for both safety and efficiency.
Traditionally, battery enclosures are made from materials like aluminium, steel, or polymers, each with certain advantages and limitations. To improve performance, newer designs are exploring advanced combinations of materials, such as honeycomb structures with composite layers. These designs help reduce weight while improving strength, durability, and energy absorption, which are critical for modern EV applications.
This project focuses on developing a lightweight and strong battery enclosure using a combination of Nylon-6/6 and an aluminium honeycomb structure. The aim is to create a design that is safe, durable, and adaptable to different battery sizes and vehicle types. By optimizing the structure and validating its performance, the project seeks to provide a reliable and scalable solution that can improve battery protection and overall vehicle efficiency in electric mobility.

Objectives:
1. To analyze existing battery pack enclosures
2. To compare materials based on mechanical and thermal properties
3. To assess safety and crashworthiness requirements
4. To develop a CAD model and perform simulations
5. To fabricate and test a prototype of the optimized casing

Methodology:
The project follows a systematic approach, as outlined in the following steps:

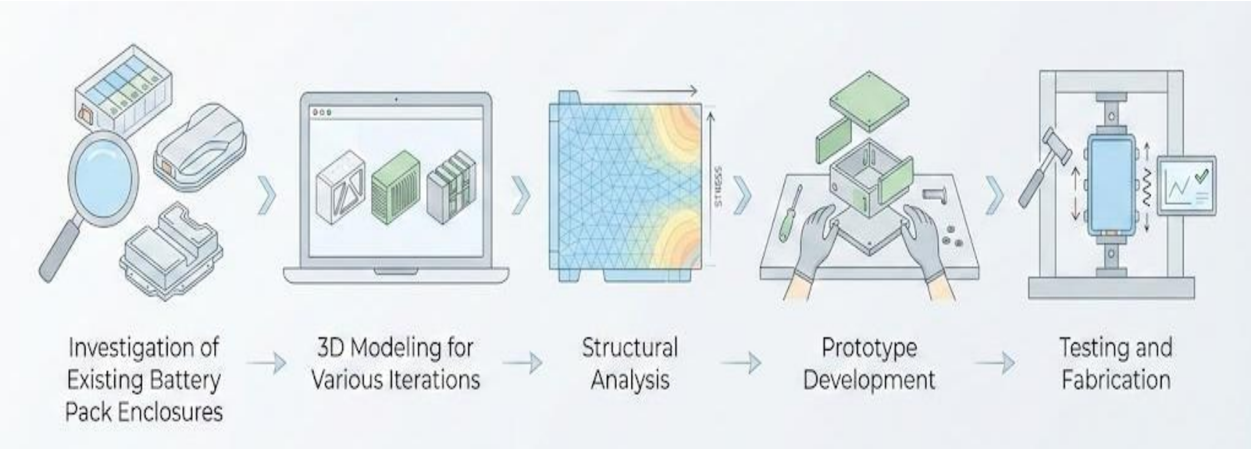

Figure 1: Graphical Methodology

1. Investigation of Existing Battery Packs
A detailed study of existing electric vehicle battery enclosures was carried out to understand their structural configuration, material composition, cooling methods, sealing mechanisms, and safety features. This benchmarking process helped establish a reference baseline for performance comparison and design requirements.
2. 3D Modelling Various Iterations
The battery enclosure was modelled using CAD software in multiple stages:
- **Base Model:** Conventional aluminium enclosure for reference.
- **Ideation Model:** Initial multi-layer sandwich design.
- **Iteration 1:** Optimized enclosure for 16-cell configuration.
- **Iteration 2:** Scalable enclosure for 77-cell configuration.

Each model was designed with proper dimensions, layered structure, internal clearance for battery cells and provisions for mounting and structural support

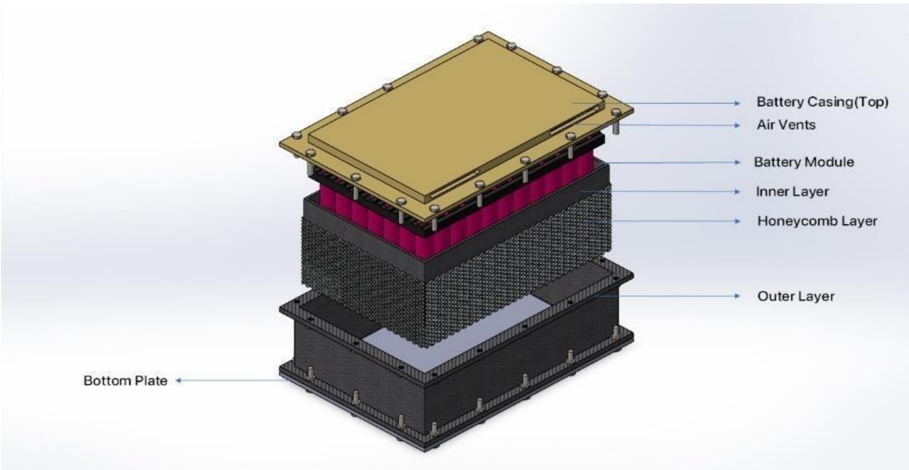

Figure 2: CAD Model for Iteration 2

3. Structural Analysis (Finite Element Analysis)
Finite Element Analysis (FEA) was performed to evaluate the structural behaviour of each enclosure model under realistic loading conditions.
- Boundary Condition: Fixed support at base (simulating chassis mounting).

- Applied Load: 1000 N lateral force.
- Dynamic Condition: 2g acceleration.

4. Prototype Development

The optimized battery enclosure design will be converted into a practical prototype by incorporating key assembly and manufacturability features. Critical aspects such as mounting points, joints, dimensional tolerances, and alignment between the Nylon 6/6 structure and aluminium honeycomb core are carefully designed to ensure ease of assembly and structural reliability. The development process also emphasized material compatibility and fabrication using 3D printing, enabling precise geometry and efficient production. Parameters such as print orientation, layer bonding, and overall structural integrity will be optimized to achieve the required mechanical performance. This approach ensures that the enclosure maintains its strength and protective function under real conditions. Additionally, it helps bridge the gap between simulation and physical implementation. The design is also adaptable and scalable for different battery configurations and applications.

5. Testing and Fabrication

The fabricated prototype is developed for detailed structural and performance evaluation under realistic conditions. Various tests are planned to assess parameters such as strength, impact resistance, and overall durability of the enclosure. The testing process helps verify whether the design meets the required safety and performance standards.

Results and Conclusion:

The base aluminium enclosure exhibited moderate deformation and was used as a reference model for comparison. The ideation-stage sandwich model showed relatively higher deformation, highlighting the need for further design refinement and optimization. A significant improvement was observed in the optimized 16-cell enclosure, which demonstrated minimal deformation and superior load distribution, primarily due to the integration of the aluminium honeycomb core.

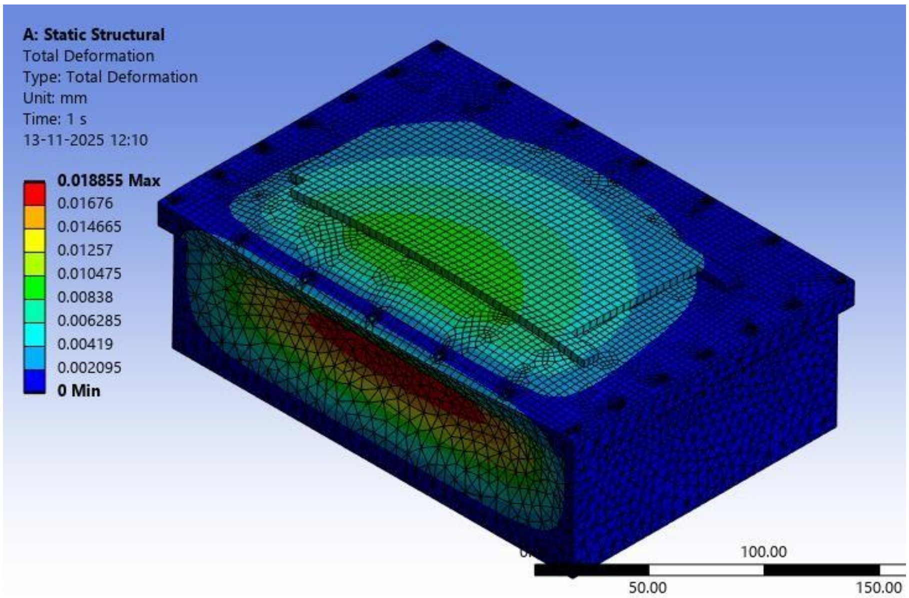

Figure 3: Result for 1000N Load Application on base on Base iteration.

The final 77-cell enclosure also maintained acceptable deformation levels despite increased size. Overall, the multi-layer sandwich structure provides improved structural performance, reduced weight and enhanced safety compared to conventional designs, making it suitable for modern electric vehicle applications.

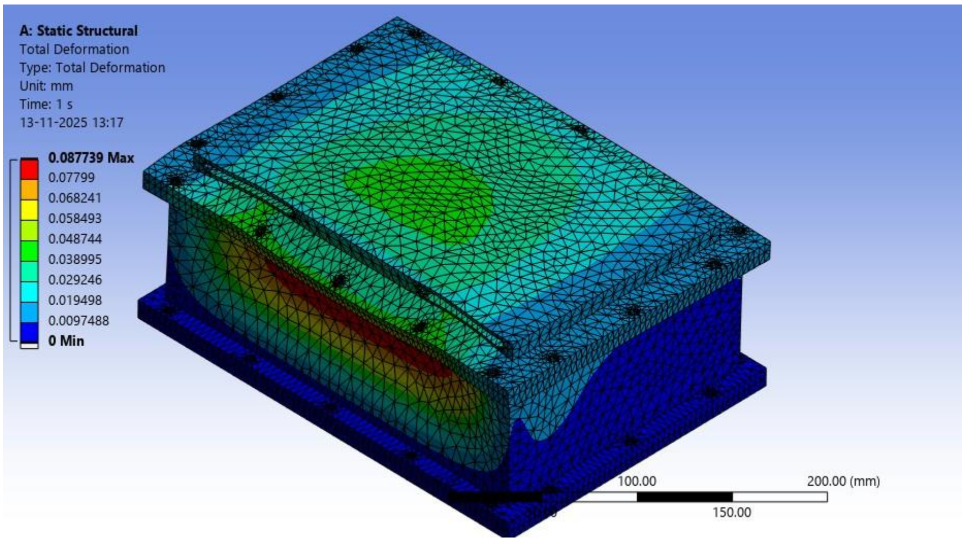

Figure 3: Result for 1000N Load Application on base on 77 cell iteration.

Project Outcome & Industry Relevance

- Developed a lightweight, multi-layer battery enclosure with improved structural performance.
- Achieved a higher stiffness-to-weight ratio and reduced deformation by combining Nylon 6/6 with an aluminium honeycomb core.
- Planned publication of research findings in a technical journal/conference to contribute to academic and industry knowledge.
- Potential for intellectual property development through patent filing for the proposed enclosure design and methodology.
- Enhanced overall efficiency by designing a strong yet lightweight structure suitable for EV applications.
- Improved safety through better load distribution, impact resistance, and structural integrity.
- Aligned with industry demand for advanced multi-material battery enclosure solutions.
- Designed a system compatible with scalable and modular battery pack configurations for different EV platforms.
- Supports manufacturers in reducing vehicle weight, cost, and improving performance.
- Demonstrated feasibility of integrating composite materials with modern manufacturing techniques like 3D printing.

Working Model vs. Simulation/Study

The main outcome of this project is to develop a physical prototype that adheres to the requirements. Currently, the project is in an intensive research and simulation phase through analytical and FEA-based studies. This approach helps identify potential design issues early, reduces development time and minimizes material costs associated with multiple physical prototypes. It also allows comparison of different materials and configurations to select the most efficient design.

Project Outcomes and Learnings

Through this project, significant practical experience was gained in the selection of appropriate materials to satisfy structural strength, thermal stability, and safety requirements for electric vehicle battery enclosures. There was increased focus towards CAD modelling, design optimization and iterative product development using advanced engineering tools, along with the application of finite element analysis for structural validation. Furthermore, hands-on exposure to additive manufacturing (3D printing) was obtained, demonstrating its effectiveness in rapid prototyping and fabrication of complex geometries.

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Future Scope:

1. Perform detailed thermal analysis to evaluate heat dissipation and ensure safe operating temperatures of the battery pack.
2. Develop and fabricate a physical prototype using the selected composite materials for real-world validation.
3. Conduct experimental testing to compare actual performance with simulation results and improve design accuracy.
4. Carry out crash and impact testing under realistic conditions to assess structural integrity, safety, and energy absorption capability.
5. Evaluate manufacturing feasibility by identifying suitable production methods and efficient assembly techniques.
6. Perform cost analysis to determine economic viability for large-scale production and industry adoption.
7. Integrate the enclosure with an actual electric vehicle system to study compatibility and packaging constraints.
8. Analyze weight distribution and its effect on overall vehicle performance and efficiency.
9. Explore further design optimization for enhanced durability, scalability, and modular configurations.
10. Facilitate the transition from simulation-based research to practical, real-world implementation and commercialization.