DESIGN AND IMPLEMENTATION OF A LITHIUM-ION BATTERY PACK WITH INTEGRATED SMART BMS FOR ELECTRIC MOBILITY

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Introduction:

The global shift toward sustainable urban transportation has necessitated the rapid development of high-performance energy storage systems. While new electric vehicle sales are increasing, the retrofitting of existing mechanical platforms like bicycles offers a faster pathway to electrification. However, standard retrofitting kits often rely on plastic housings that lack the structural integrity required for varied road conditions. This project addresses the critical disconnect between mechanical safety and electrical performance. By utilizing 52 high-density Samsung 21700 NMC cells, the system achieves a superior energy-to-weight ratio compared to the 18650 format. The significance of this work lies in the integration of a 3mm Mild Steel (MS) enclosure to ensure crashworthiness and a programmable Daly Smart BMS to manage high-current charging cycles. This framework provides a reliable, high-torque 48V solution for the growing Indian micro-mobility market.

Objectives:

1. To engineer and validate a high-capacity 48V battery system tailored for electric mobility.
2. To Design a monolithic 3mm Mild Steel enclosure to provide superior impact resistance and structural rigidity
3. To Implement a 13S4P topology with 21700 NMC cells and nickel interconnects to manage 10A fast-charging.
4. To Integrate a Daly Smart BMS for real-time sensing and programmable control of safety thresholds.

Methodology:

The project utilizes a modular engineering approach combining structural shielding with digital management logic. The mechanical phase involves the fabrication of a monolithic cuboid casing using 3mm MS sheets to maximize "crush resistance".

Internal non-conductive spacers and high-temperature Kapton tape are applied for dielectric shielding. For electrical integration, 52 Samsung INR21700-50S cells are voltage-matched to a ±0.01V tolerance. High-purity nickel strips are utilized for interconnects, bonded via resistance spot welding to minimize the Heat Affected Zone (HAZ) and Electrical Contact Resistance (ECR).

The Daly Smart BMS is integrated via a UART interface, allowing for the dynamic tuning of Over-Voltage (4.2V) and Under-Voltage (3.0V) protection thresholds. Thermal management is validated by modeling the 3mm MS casing as a passive heat sink to dissipate I^2R losses during high-current 10A profiles.

Results and Conclusion:

Experimental validation confirmed the stability of the 13S4P array, maintaining a steady charging current of 5.97A at 43.3V, matching the intended 6A profile with 99.5% accuracy. Structural simulations showed that under a 200N load, the peak von Mises stress (1.422×10^7 N/m^2) remained well below the material's yield strength (3.516×10^8 N/m^2)

Thermal modeling confirmed uniform dissipation, keeping internal temperatures below the 55°C BMS trip point. The total energy density was verified at 960Wh with a measured capacity of 20.6Ah. In conclusion, the monolithic MS enclosure successfully protects the cell matrix from mechanical failure, while the Smart BMS ensures longevity, supporting a projected 2500+ cycle life.

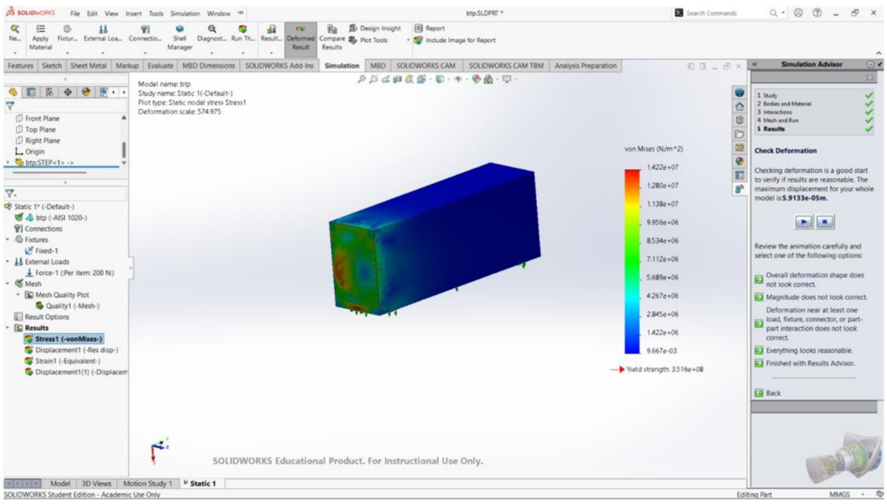

Figure 1: Von Mises stress distribution of the mild steel enclosure under static load, indicating maximum stress concentration near the fixed support region.

Project Outcome & Industry Relevance:

The project delivers a scalable, high-strength energy storage solution that exceeds the safety margins of conventional plastic-encased packs. It contributes to the field by demonstrating that mild steel is a cost-effective, durable alternative to lightweight alloys for electric micro-mobility. Industrially, this system can be applied in e-bike retrofitment kits, delivery scooters, and light electric vehicles (LEVs). The smart monitoring capabilities allow fleet operators to track State of Health (SoH) in real-time, reducing downtime through preventive maintenance.

Working Model vs. Simulation/Study:

This project involved the development of a physical Working Model supported by analytical Simulations.

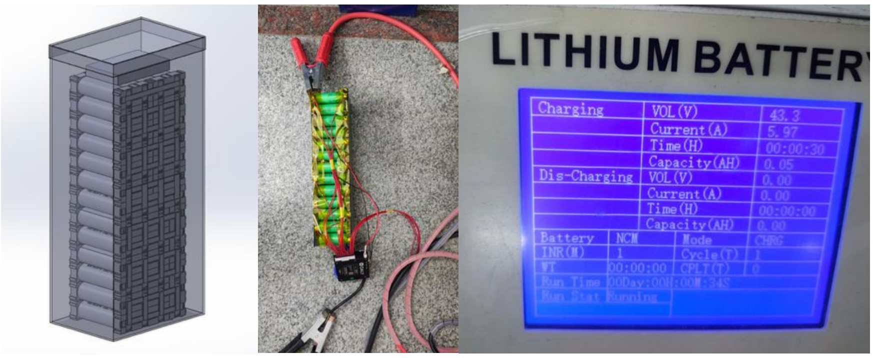

Figure 2: (a) CAD model of battery pack, (b) fabricated 21700 cell assembly with BMS, and (c) real-time charging data from battery testing unit.

Project Outcomes and Learnings:

Key outcomes include a functional 48V 20Ah REESS and a validated structural casing. Through the design process, the team learned the complexities of resistance spot welding and the importance of cell-matching in parallel configurations. We gained practical experience in programming BMS logic and interpreting FEA (Finite Element Analysis) stress plots to optimize material thickness.

Future Scope:
The future scope of this project includes:

1. Explore the integration of active liquid cooling systems within the MS enclosure to support "Ultra-Fast" 20A charging profiles.
2. The current design can be extended by developing a CAN-bus communication interface for deeper integration with vehicle-level controllers.
3. Development in the MS chassis could include topology optimization to reduce overall weight while maintaining current safety factors.
4. Study of secondary use-cases for the pack in stationary energy storage after its automotive cycle life could enhance its overall sustainability.