Advances in Multimaterial EV Battery Enclosures

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Novi, Mi

Competence in Automotive-Composites Engineering & Development Services

Structural Components  Chassis / Suspension  Battery Enclosures  Gas Cylinders
Agenda

- Introduction
- Electric Vehicle Battery Enclosures
  - Requirements
  - Concept Study
- Study Results
- Conclusions & Outlook
Leading composites engineering services consultancy

- Renewable/Wind Energy
- Marine
- Automotive
- Civil
- Oil & Gas
- Materials Industry

STRUCTeam Ltd. Introduction

- batteries
- composites
- structural
- engineering

2025

~ 80% of revenue base

2020

Renewables
- Battery Enclosures
- Pedestrian Bridges
- PULLWIND

2015

Transportation
- CompoSIDE

Other sector – 20% of revenue

STRUCTeam Formation

Date: 11/10/2021

STRUCTeam Ltd CONFIDENTIAL
Sustainability Focus at STRUCTeam

AUTOMOTIVE

- Electric Vehicle (EV) Batteries
- H2 Tanks for Fuel Cell Electric Vehicles (FCEV)
- Safety Parts Light Weighting

CROSS SECTOR FOCUS AREAS

- Development/introduction of sustainable designs and materials
- Investigation of CO₂ balances & sustainability KPIs.

Date: 11/10/2021
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Slide: 4
Impact of Global Market Trends

I) Powertrain Shift
- NEV: BEV, FCEV
- Higher weight vs. ICEs

II) Autonomous Driving
- Increased safety requirements

III) New Ownership Models
- More users / mileage
- Higher durability

IV) Trend I)-III) accelerate product commoditization
- New technologies become important product differentiators

Opportunities for NEW STRUCTURAL LIGHT-WEIGHT Materials
# Vehicle Segment Opportunities

<table>
<thead>
<tr>
<th>Vehicle Segment</th>
<th>Applications</th>
<th>New Material Opportunity - Growth Outlook -</th>
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</table>
| **Commercial vehicles** | • Energy storage / powertrain  
• Exterior  
• Chassis | Strong incremental - select opportunistic |
| Bus  
Trucks  
LCV – HCV | | |
| **Premium** | • Energy storage  
• Structural – semi structural | Strong - Exponential |
| SUV  
Full-size  
Mid-size | | |
| **Compact** | • Energy storage | Incremental |
| | | |
| **Super premium** | • Structural  
• Energy storage  
• Exterior / Interior  
• Chassis | Strong incremental |
| Super car  
Luxury vehicles | | |

Source: Zoox  
Source: NIO  
Source: BMW  
Source: Lamborghini
Industry Challenges – EV Energy Storage Systems
(for BEV, FCEV, HEV)

Source: Automotive Council Electrical Energy Storage Roadmap 2017

+ Coming decisions will be influenced by growing supply issues
Agenda

Introduction
Electric Vehicle Battery Enclosures
  Requirements
  Concept Study
Study Results
Conclusions & Outlook
Electric Vehicle Battery Enclosures
(for BEV, FCEV, HEV)

Evolving vehicle architectures make composites an attractive material choice for the enclosures of future EVs. The average enclosure weighs 80-150 kg.

CHALLENGES
- Many & evolving requirements
- Evolving battery cell chemistry
- Complexity in design & development
- ...

DEVELOPMENT NEEDS
- Cost, size, weight* reduction
- Improved structural & functional integration
- Simpler thermal management & EMI solutions
- ...

* Cost & weight of enclosure 10-25% of battery system
Market Share for Passenger & Commercial Vehicles by Powertrain Technology

- Battery Electric Vehicles (BEV): 2030 = 28 Mil. / 2040 = 64 Mil.
- Fuel Cell Electric Vehicles (FCEV): 2030 = 1.1 Mil. / 2040 = 7.7 Mil.
Multi Material Composite Enclosures
- Industry Progress -

Concept Design
TRL 1 - 3

Commercial Feasibility
TRL 4

Proof of Concept
TRL 5 - 6

Prototype
TRL 7 - 8

Preproduction
TRL 9

Serial Production

2023 – 2025

Current Status

Source: Chevrolet

Source: Rivian

Source: Porsche
**Enclosure Structural Requirements**
(for BEV, FCEV, HEV)

- Heat shielding
- Li-Fire protection
- EMI/EMC shielding
- Electrical insulation
- Thermal management - cooling
- Side, rear, front crash
- Water ingress

**Load Spectrum from**
- Battery weight
- Driving operation / BiW interaction
- Crash events
- ... 

**Main Load Origin**
- Weight of battery cells & modules, typical 300-700kg
- Interactions with BiW architecture
- Driving operation
- Impact during operation
- Crash events
- External & internal pressure build up

**Allowable Enclosure Structural Response**
- Intrusion protection
- Minimum deformation
- Vibration control
- Potential BiW architecture reinforcement requirement
Enclosure Requirements - Fire
(for BEV, FCEV, HEV)

- When battery temperatures exceed 150°C, there is a high risk of thermal runaway (typical ignition temp. ~200°C)

- Many national and international standards & requirements

- Requirements will get more stringent in future

- Protecting passenger and batteries from thermal runaway events remains to be a key challenge in automotive battery pack/enclosure design
Why Multimaterial Composite Designs?

- Capability to integrate many functions
  - Structural functionality
    - Primary loads
    - Secondary loads
  - Thermal management
    - Cooling / heating / insulation
    - Fire protection
  - Reduce # of screws, bolts, joints, ...
  - Simplify sealing provisions
  - Noise vibration and harshness (NVH)
  - Underbody aerodynamics
- Best material & process for each application / task
- Lower system weight & life cycle cost
  - Reduction in Assembly Efforts
  - Weight Reduction
  - CAPEX & Direct Production Cost Reduction
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Study Sponsors & Partners

- Core Materials
- Epoxy Resins
- Reactive Polymers & Flame Retardants
- Adhesive, Sealants & Coatings

We thank our partners for their project support!
**Enclosure References & Concept Study Benchmark**

**Enclosure Reference Examples**

- Mercedes EQC
- Ford Mach E
- Jaguar I-PACE
- 21' Tesla Model 3
- Audi e-tron
- BMW iX3
- Polestar 2
- VW ID4

**Benchmark Specification**

- AL enclosure (extrusion, die castings, deep draw)
- High specific energy density (> 130Wh/kg)
- ~ 80 kWh capacity
- Height: 140mm
- Uses cells that are not-structurally loaded
- Weight: among lightest in industry, ~ 25% of total weight is for underbody protection
- Enclosure includes liquid cooling circuit

Selected benchmark captures many of current trends in enclosure designs and is challenging target in terms of cost & weight
Composite Battery Enclosure Concept Study

Concept A - Non-Structural Enclosure
- Minimized contribution to primary loads
- No support of BiW structure in crash load cases
- Minimized number of connection points to chassis structure

Design Specifics
- Designed for ease of manufacturing & low cost
- Maximized available cell/module space
- High degree of functional integration

Concept B - Structural Enclosure
- Strong contribution to BiW rigidity in bending & torsion
- Supports BiW structure in crash events, mainly in side impact
- Takes additional function to support BiW

Design Specifics
- Design for ease of manufacturing & lost cost
- Designed for weight effectiveness
- High degree of functional integration

Date: 11/10/2021
# Key Design Features

<table>
<thead>
<tr>
<th></th>
<th>Industry Benchmark</th>
<th>Non-Structural</th>
<th>Structural</th>
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</table>
| **Basic Description**    | • AL sheet upper cover  
                           | • AL extrusions/sheets/cast lower tray, beam reinforced | • Composite upper cover  
                           | • Composite lower tray |
| **Material Combinations**| > 75% AL  
                           | > 60% FRP  
                           | > 60% FRP  
                           | < 10% ST  
                           | < 15% ST & AL  
                           | < 15% ST & AL  
                           | > 10% Sealants, Adhesives, FR Layers  
                           | < 40% other non-metallic materials |
| **Cells/modules are structural** | **No**  
                           | **No**  
                           | **No**  
                           | **Slightly**  
                           | **No**  
                           | **Substantially** |
| **Enhances BiW torsional stiffness** | **Yes**  
                           | **No**  
                           | **Yes**  
                           | **No**  
                           | **Substantially** |
| **Side crash / res. load support** | **Yes**  
                           | **No**  
                           | **Yes**  
                           | **No**  
                           | **Yes** |
| **Takes additional BiW load** | **No**  
                           | **No**  
                           | **Yes**  
                           | **Yes**  
                           | **Yes** |
| **Includes cooling circuit** | **Yes**  
                           | **Yes**  
                           | **Yes**  
                           | **Yes**  
                           | **Yes** |
| **Improved thermal insulation** | **No**  
                           | **Yes**  
                           | **Yes**  
                           | **Yes**  
                           | **Yes** |
| **Thermal runaway protection** | **No / Yes***  
                           | **Yes**  
                           | **Yes**  
                           | **Yes**  
                           | **Yes** |
| **Best Part Cost Index**   | 2 – 2.5  
                           | 1  
                           | 2  
                           | (1=lowest, 5=high)  
                           | * Depends on country of delivery |

* *Depends on country of delivery*
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Bill of Materials

Concept A - Non-Structural Enclosure

Bottom tray

Concept B - Structural Enclosure

Top cover

Bottom tray

Weight & cost effective multi-material design
## Results

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• Composite lower tray | • Composite upper cover  
• Composite lower tray |
| **Material Combinations** | > 75% AL  
< 10% ST  
> 10% Sealants, Adhesives, FR Layers | > 60% FRP  
< 15% ST & AL  
< 40% other non-metallic materials | > 60% FRP  
< 15% ST & AL  
< 40% other non-metallic materials |
| **Enhances torsional stiffness** | Slightly | No | Substantially |
| **Side crash / res. load support** | Yes | No | Yes |
| **Takes additional BiW loads** | No | No | Yes |
| **Includes cooling circuit** | Yes | Yes | Yes |
| **Improved thermal insulation** | No | Yes | Yes |
| **Thermal runaway protection** | No / Yes* | Yes | Yes |
| **Enclosure Weight** | 100 % | 91 % | 70-90 % |
| **BiW Wt Savings** | 0 % | 0 % | 10-50 kg |
| **Available space for batteries** | 100 % | 105 % | 100 % |
| **Best Part Cost Index**  
(1=lowest, 5=high) | 2 – 2.5 | 1 | 2 |

* Depends on country of delivery
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Conclusions

- Automotive industry requirements for EV batteries will continue to evolve
- Fire safety requirements will further increase
- Reducing cost and weight of battery enclosures are a major focus area for OEMs
- Multimaterial designs using non-metallic solutions are at an infant stage

- Multimaterial composite battery enclosures can help to reduce system weight & cost
- Structural battery enclosures can achieve secondary savings, such as BiW weight reduction
Next Steps & Outlook

- Joint proof of concept validation activity, including OEM & tier specific requirements
- Implement viable multi-material solutions in OEM’s own developments
- Embodied CO$_2$ analysis and end of life solutions
- Formation of Phase 2 program including needed project partner forum