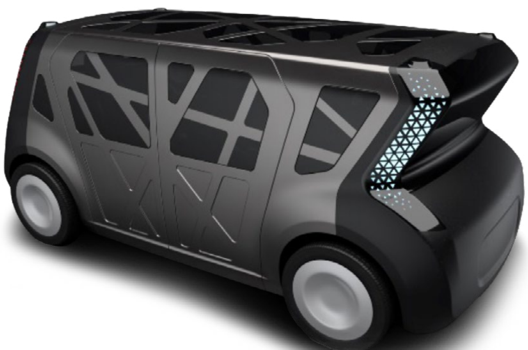
Steel E-Motive
Shaping the Future of Sustainable Transportation ISSUE 3
Technical Microstudies Highlighting Design and Performance Innovations for Steel E-Motive

Steel E-Motive's Intelligent Battery Packaging Offers Mass, Cost Savings for BEVs



INTRODUCTION

Urbanization and Net Zero Emissions targets are key contributors of the transportation shift to mobility on demand in densely populated urban environments. It's here that the mobility industry anticipates significant growth in ride sharing, with emphasis on the use of autonomous vehicle technologies and electrification to achieve that goal. WorldAutoSteel's Steel E-Motive program demonstrates autonomous ride-sharing concepts that maximize occupancy and comfort through unique seating configurations and easy vehicle access, while offering a clear path to Net Zero.

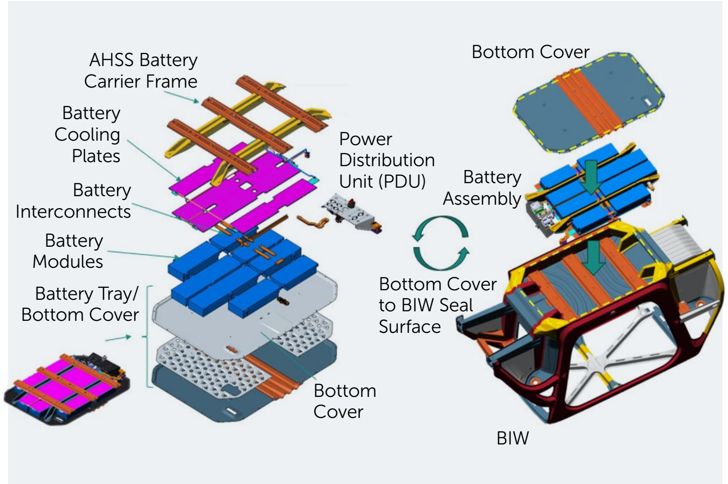
A BEV's battery technology is a critical piece of its propulsion system. Battery cells, chemistry technologies and integration of cells into the vehicle continue to evolve rapidly, resulting in improvements in vehicle performance, range, safety and reliability. One key objective of the Steel E-Motive programme was to embrace future battery cell technologies, whilst demonstrating how the latest Advanced High-Strength Steels (AHSS) can deliver and support safe, sustainable and lightweight battery systems.

STEEL E-MOTIVE'S BATTERY DESIGN CONCEPT

Steel E-Motive is characterized by two vehicle variants: SEM1, a four-passenger commuter for urban transport, and SEM2, a stretched version with additional passenger/luggage capacity for extended travel. Vehicle performance simulation calculations determined that a 75kWh battery was required for the SEM1 vehicle and its daily Mobility as a Service duty cycle. The battery form factor and cell technology was specified as "intentionally agnostic," meaning that the Steel E-Motive vehicles could accommodate different battery cell types (e.g. pouch, prismatic, cylindrical) and different cell chemistries (e.g. NMC, Lithium-ion, solid state). This would ensure ease of adoption by any vehicle manufacturer and accommodate future battery technologies.

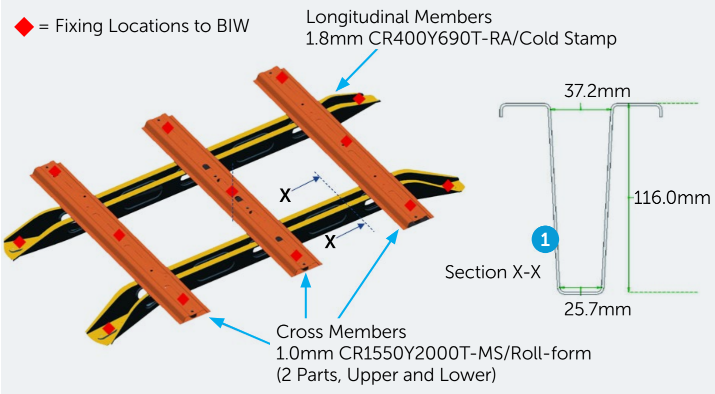
Present-day passenger car battery systems feature an enclosed, metallic housing, encapsulating the battery cells and/or modules, providing protection from external protrusions and impacts, and sealing the battery from external elements. The Steel E-Motive battery concept, illustrated in Figure 1, features a "coverless" system, eliminating the main battery housing component and mounting battery modules to the body structure via an intermediate Advanced High Strength Steel carrier frame. This approach is commonly referred to as "cell to body." The removal of the battery housing provides additional space for batteries, enabling the interior floor of the body structure to be flat and lower, and allows for easier, more direct access to the battery components by removal of the bottom cover. The body-in-white and bottom covers combine to provide a protective structure around the battery, saving significant mass and cost. A water-glycol system provides battery cooling, with each of the eight modules featuring a pressure-fed cooling plate.

Figure 1: Steel E-Motive Battery Concept and Installation to Body Structure



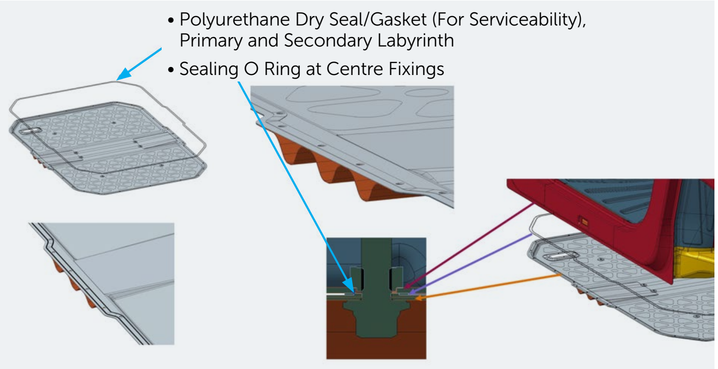
The battery carrier frame (Figure 2) features two cold-stamped longitudinal members in CR400Y690T-RA ("Trip 690"), which are bolted to the lower parts of the front and rear BIW crash mid rails, forming a complete underbody frame structure. This contributes to very good static and dynamic (NVH) structural performance of the complete vehicle, resulting in a comfortable passenger experience. Ultra-High Strength Steel (UHSS) CR1550Y2000T-MS lateral cross members provide the mounting locations and fixings for the battery modules, cooling plates and Power Distribution Unit. The battery frame cross members connect to reciprocal cross members on the BIW, providing significant contributions to side crash protection.

Figure 2: Steel E-Motive Battery Carrier Frame



Passenger car batteries must be sealed from external elements to prevent leakage of any cell gases into the passenger compartment. They also require pressure relief valves to enable safe venting of gases and pressure buildup in the battery compartment. As the Steel E-Motive battery design is coverless, the sealing function is provided by the BIW and the bottom cover. A polyurethane two-layer dry gasket provides the seal between the BIW and the bottom cover, as shown in Figure 3. The BIW structure is engineered to have a flat surface on the flange seal, enabling the BIW panels in the battery compartment to be fully sealed. The fixings from the bottom cover to BIW and battery frame to BIW are sealed with standard O-rings. Steel E-Motive is engineered to meet the IP6k9k and IP67 ingress protection ratings.

Figure 3: Steel E-Motive Battery Sealing Design



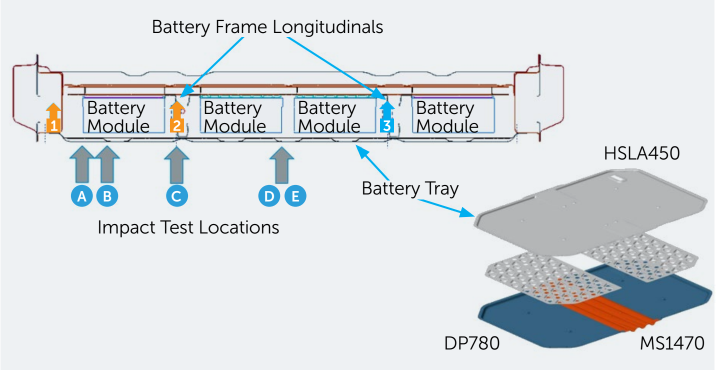
PROTECTION OF BATTERY FROM VEHICLE COLLISIONS, ROAD DEBRIS AND ACCIDENTAL JACKING

Passenger car batteries must be protected from damage or rupture of any battery cells, as this can result in a thermal runaway event – subsequent fire and the release of toxic gases. Damage can be caused by high-speed road collisions, impact underneath the vehicle from significant road debris or jacking/lifting the vehicle at an incorrect location.

The 32kph rigid side pole crash test is one of the most challenging for protection of the battery, due to the high, concentrated load and the high energy values involved. A previous microstudy publication titled "Steel E-Motive's Body Structure Concepts Meet Stringent Side Crash Requirements" describes the body structure design and the application of AHSS grades that provide excellent protection of the batteries for high-speed side crash conditions.

Protection of batteries from significant road debris and accidental jacking procedures is achieved through a combination of the carrier frame design and the bottom cover, detailed in Figure 4.

Figure 4: Section Through Body Structure and Battery Showing Strategy for Underbody Damage Protection



If a vehicle underbody is impacted at locations 1, 2 or 3, then the load is reacted by the BIW rocker (1) or the battery frame longitudinal (2) and (3). For impact locations A, B, D and E, the bottom cover design provides the primary protection. The bottom cover comprises a four-sheet sandwich construction. The middle sheet is produced from HSLA450 with crimped stamped profiles, increasing the overall vertical (Z) height of the panel. This increases the bending moment of inertia of the panel, improving stiffness and resistance to impact load. The HSLA450 upper panel provides the primary sealing interface/cover to the battery. The lower sheet is high strength DP780 with a centre MS1470 Tailor Welded Blank, which contributes to side crash performance. With the battery modules effectively suspended from the carrier frame and body structure, a clearance air gap of 3-5mm is achieved between the bottom cover and the lower surface of the battery. This clearance allows some deflection of the bottom cover under impact, minimizing contact with the battery modules.

BATTERY ASSEMBLY, REPAIR AND SERVICING

SEM Engineers accounted for design considerations for battery system assembly and installation into the vehicle, as well as service and repair throughout the life of the vehicle. The Steel E-Motive concepts benefit from generally good service and repair attributes, as direct access to the major battery components can be achieved by removal of the bottom cover.

Conversely, conventional sealed pack units require complete removal of the battery pack from the vehicle, followed by removal of the battery cover. Direct access to the battery compartment enables rapid inspection and repair of components such as cooling plates, modules and bus bars. This is particularly advantageous given the high utilisation and anticipated duty cycle of the vehicle operating as a Mobility as a Service application.

The battery system can also be assembled by a supplier and then delivered for vehicle assembly installation. As the battery is coverless, a re-usable, returnable transportation stillage (encasement) would be required due to the exposed high-voltage components.

AHSS APPLICATIONS

The table below summarizes the extensive use of AHSS in the battery carrier frame system to achieve the positive attributes and performance outlined above.

Component	Steel Grade (MPa, UTS)	Fabrication method	AHSS application
Battery frame longitudinal	1.8mm CR400Y690T-RA	Cold stamp	RA/Trip provides very good strength and cold stamp formability, required for the deep draw profile.
Battery cross members	1.0mm CR1550Y2000T-MS	Roll form	UHSS grade, provides side crash and battery protection performance. Geometry profile enables roll form.
Bottom cover, top sheet	0.5mm CR340Y/450T-LA	Cold stamp	0.5mm gauge contributes to lightweight bottom cover design.
Bottom cover, middle sheet	0.5mm CR340Y/450T-LA	Cold stamp	0.5mm gauge contributes to lightweight bottom cover design. Crimped stamped shape increases z height and bending stiffness.
Bottom cover, lower sheet	TWB (A) 0.7mm CR420Y780T-DP (B) 0.8mm CR1200Y1470T-MS	Tailor Welded Blank, cold stamp	DP780 provides good strength-weight for impact protection. MS1470 contributes to side crash performance.

CONCLUSION

The battery system of modern passenger cars is a fundamental, integral part of the vehicle propulsion system. Applying the latest Advanced High Strength Steel grades to Steel E-Motive's battery architecture resulted in an innovative design that can accommodate a range of cell chemistries and types for both current and future battery platforms.

The SEM engineering team achieved very good cost and weight savings with the innovative, cell-to-body battery carrier frame design, while ensuring safety and protection using Advanced High Strength Steel grades on the battery's bottom cover and BIW structure. The battery is sealed and vented in the body structure cavity through the use of the BIW floor and joints, a two-part polyurethane perimeter dry seal, O-rings on the bolted connections and a pressure relief valve venting to the cabin. Removal of the AHSS bottom cover provides direct access to the major battery components, enabling efficient, cost-effective service and repair and contributing to lower operating costs – all well-suited for the higher operational utilisation of a Mobility as a Service vehicle.

For additional details on the Steel E-Motive project, including specific design and simulation results, visit **steelemotive.world/resources**