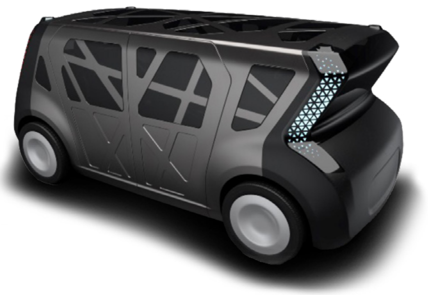
Steel E-Motive

Shaping the Future of Sustainable Transportation ISSUE 6

Technical Microstudies Highlighting Design and Performance Innovations for Steel E-Motive

Closer Look: Advanced High-Strength Steel Grade Applications for Steel E-Motive's Concept Vehicles

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 emissions targets. WorldAutoSteel's Steel E-Motive (SEM) program demonstrates autonomous ride-sharing EV concepts that maximize occupancy and comfort through unique seating configurations and easy vehicle access, while offering a clear path to Net Zero.

These concepts also address the needs of the mobility service provider – where a small vehicle footprint for ease of maneuverability and curbside access can minimize total cost of vehicle production and deployment, helping deliver a profitable business model.

Finally, SEM's vehicles are intended to operate in mixed-mode traffic with a maximum speed of 130 km per hour; thus, it was critical to engineer these vehicles to meet global high-speed crash standards. Our engineering strategy focused on expansive application of modern Advanced High-Strength Steels (AHSS), where properties could be "tuned" to meet functional requirements, including the protection of both the occupants and battery.

Extensive AHSS Portfolio Enables Body Structure to Be Optimised to Deliver Low Cost, High Strength, High Stiffness and Sustainable Performance

The mechanical properties of Advanced High-Strength Steels are modified at the production stage by the addition of low quantities of alloying elements, and through steel's thermo-mechanical processing, resulting in vastly different strength and ductility characteristics. Each AHSS grade can also be supplied in a variety of gauge thicknesses, allowing engineers to tune material performance to meet functional requirements on the automotive component and body structure. The different steel grades are grouped by product families, named according to their microscopic grain structure and/or forming process. A Global Formability diagram is commonly used to demonstrate the elongation and UTS properties of AHSS product families. For the SEM programme, members of WorldAutoSteel contributed a total of 64 unique grades of AHSS to the engineering design team, highlighted in **Figure 1** below.

The grade selection considers many material attributes, including part manufacturing and assembly/joining. For example, the front crash structure requires high levels of energy absorption for the motor longitudinal rail – AHSS grades with very good ductility, such as Dual Phase, are ideally suited for this application.

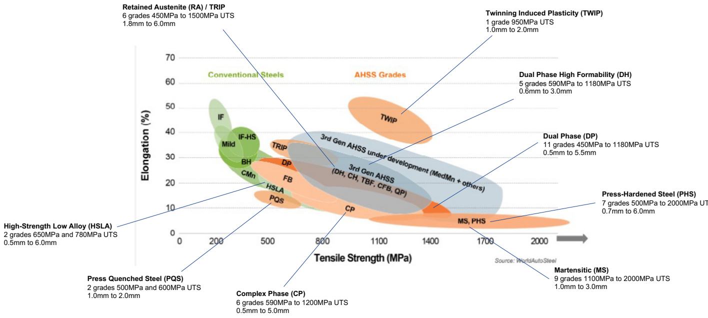


Figure 1. AHSS Global Formability Diagram and portfolio of grades and gauge thickness ranges made available for the design of the SEM body structures.

Similarly, the passenger compartment requires crush resistance and very high strength – Hot-Formed, Press-Hardened and Martensitic AHSS grades with ultimate tensile strengths >1500MPa are matched well to these crash protection structures.

Nominal and Alternative AHSS Grades Applied in the Steel E-Motive Body-in-White

Figure 2 shows the distribution and utilisation of AHSS grades for the SEM1 BIW design, which is a four-passenger vehicle concept targeting urban transportation. The body structure is comprised of almost 66% of steels ranging from 1000MPa to 2000MPa tensile strength, dominated by Press-Hardened Steel and Martensite grades. Dual & Complex Phase grades provide high-strength properties from 500MPa to 1000MPa. The latest 3rd generation steels provide high strength (up to 1500MPa UTS) and improved cold stamped formability characteristics, desirable where press hardening is unavailable. High-Strength Low Alloy (HSLA) and Bake Hardenable (BH) steel grades are particularly suited to parts of the body structure where high strength is not specifically required, and for external body panels where a very good "A" surface quality and finish is required.

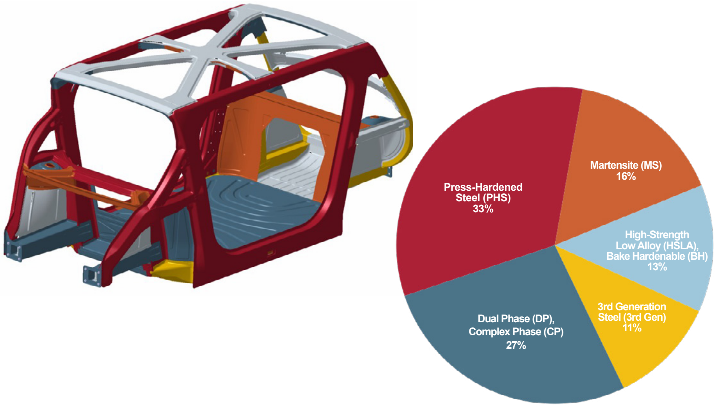


Figure 2. AHSS grade utilisation for SEM1 BIW

Of the 64 AHSS grades made available for the development of the SEM1 BIW, 23 unique grades were selected for the final design. The pareto distribution is shown in **Figure 3**. **Figure 4** shows the distribution of BIW panel gauge thickness.

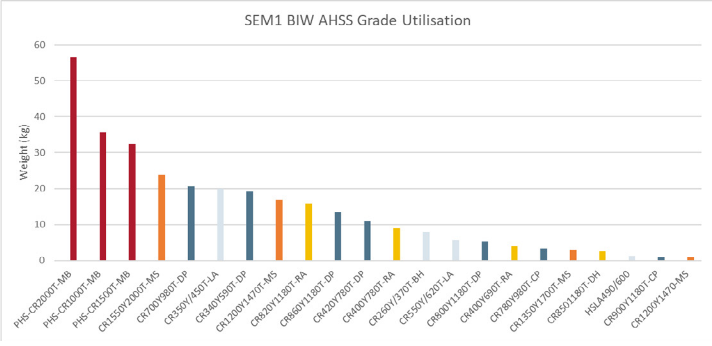


Figure 3. SEM1 BIW AHSS grade distribution (pareto)

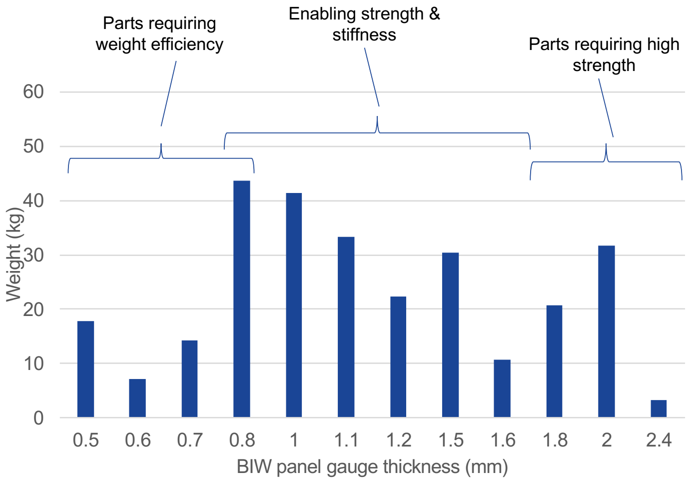


Figure 4. SEM1 BIW gauge thickness distribution

Panel gauge thicknesses are selected based on strength (crash critical zones), general body stiffness (in stiffness critical zones, such as floor and rear) and body structure requirement for low weight (i.e. large body panels). The average gauge thickness of the BIW structure is 1.1mm, which contributes to the overall weight-efficient design. The combination of AHSS grade and gauge thickness availability enables engineers to deliver an optimised BIW design, achieving the strength, stiffness, weight, manufacturing and cost requirements. With manufacturing simplicity and cost reduction becoming more important, steel grade consolidation can be achieved by combining lower utilised AHSS grades with those with slightly higher mechanical strength properties or through gage commonization.

Due to the breadth and global differences in AHSS grades manufacture and availability, variations in the application of steel grades to body structures can occur, whilst delivering comparable structural performance and weight. To demonstrate this, an *alternative AHSS grades study* for the SEM1 BIW was undertaken, as shown in **Figure 5**. The study shows the potential to substitute reasonable quantities of 3rd generation AHSS for Dual & Complex Phase and Martensitic grades, without compromising the structural performance of the body structure.

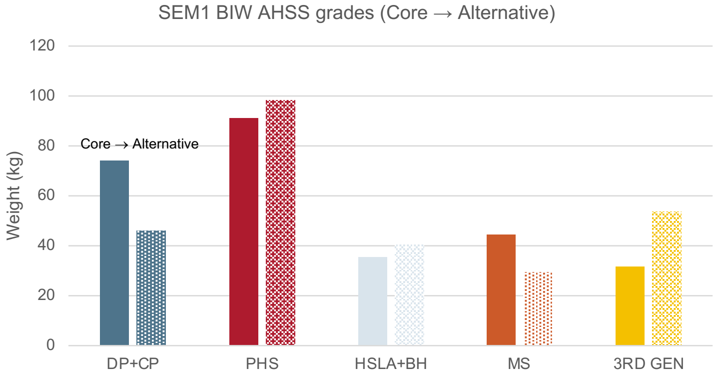


Figure 5. SEM1 BIW alternative AHSS grades study. AHSS grade utilisation by weight

Steel E-Motive BIW Design Innovations Using AHSS

The SEM body structure features unique design innovations using the latest AHSS grades. The side door ring outer (**Figure 6**) features a four-part Tailor Welded Blank (TWB) using Press-Hardened Steels ranging from 1000 – 1900MPa in strength; here the material properties are tuned to provide the structural performance required for the front, side and rear crash performance. The A pillar (1.2mm PHS1900) requires very high strength to provide protection for the seated occupants in front and side crash load cases. The side crash protection strategy requires the controlled collapse and crush of the side outer structure – the lower-strength PHS1000 in 1.5mm for the cant rail upper and lower rocker outer panels provides this “soft zone” performance. The rear C pillar provides rear and side crash protection but has a lower strength requirement than the A pillar; therefore, a 0.8mm PHS1500 grade was selected to provide the appropriate strength with good weight efficiency. Excellent material utilisation (low scrap rate) is assured due to the tailor welded blank approach. Additionally, this part is considered “B” surface quality, as it is exposed only when the side doors are opened. Further cost and weight savings are enabled as the vehicle does not require a conventional “body-side outer” “A” surface panel.

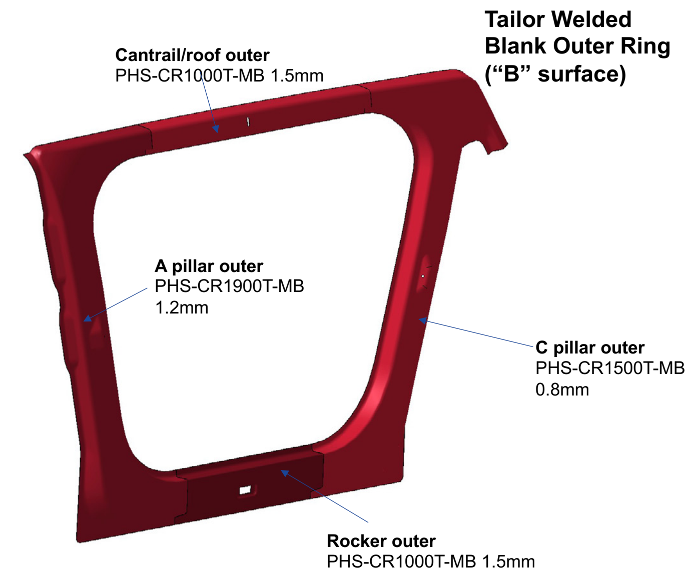


Figure 6. SEM BIW door ring outer. Four-part tailor welded blank, single hot stamping

The SEM1 concept is predicted to achieve an IIHS “good” rating for side crash performance (highest rating). A key component of the side crash structure is the rocker hex absorber, comprised of two roll-formed, Dual Phase 780MPa UTS parts, which, when joined (spot-welded), form a hexagonal section profile which is perpendicular to the direction of side crash barrier motion. The component is placed inside of the main rocker section, supported and spot-welded in place by a supporting shelf. The hexagonal section corner profiles, Dual Phase AHSS with high elongation and 0.7mm gauge thickness result in a lightweight, cost-efficient structure converting side crash energy to crush energy, resulting in reduced structural intrusions and improved crashworthiness.

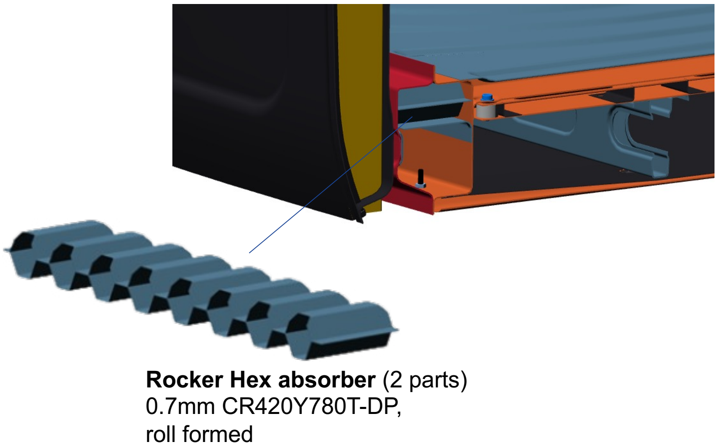


Figure 7. SEM1 BIW rocker hex absorber

The rear pillars (D pillars) of the SEM1 BIW are made from hydroformed TRIP690 AHSS tubes and form the major part of the rear torsion hoop structure, providing a significant load path contribution to the global static and dynamic body stiffness. Hydroforming achieves a uniform strength profile while minimizing material scrap, lowering cost and reducing manufacturing emissions. The single piece tubes effectively consolidate up to four (cold-stamped) parts into one single part, eliminating a total of eight parts in the BIW. Single-sided resistance spot-welding is used as the primary joining method for neighbouring parts.

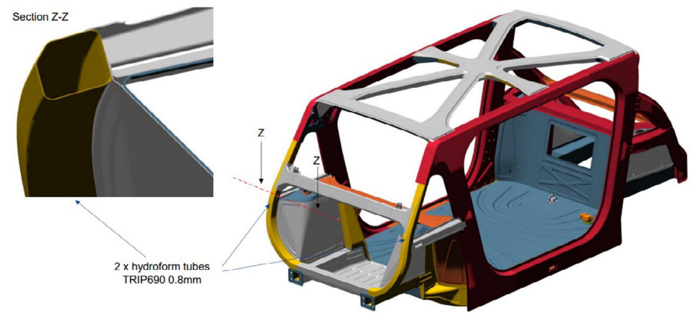


Figure 8. SEM1 BIW hydroformed tube D pillars

Steel E-Motive BIW Joining Technologies and Considerations
The SEM concept design applies a relatively conventional approach for the high-volume production of a stamped and fabricated body structure. Resistance spotwelding is used as the primary joining method, with the majority consisting of two-sheet joining. In locations where three- and four-sheet/flange joints are required, careful consideration and optimisation of the material grade stack-up and spotwelding parameters (such as the welding electrode dimensions, clamping force and the electric current magnitude and profile) ensure that a robust joint strength can be achieved. The BIW floor panel features a constant perimeter laser weld. This is required to achieve the permanent gas seal between the (module to body) battery and occupant compartments. A modest quantity of structural adhesive is placed at joining locations where additional strength and stiffness is required.

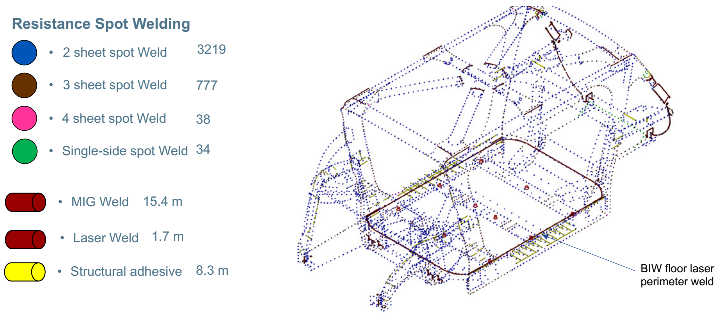
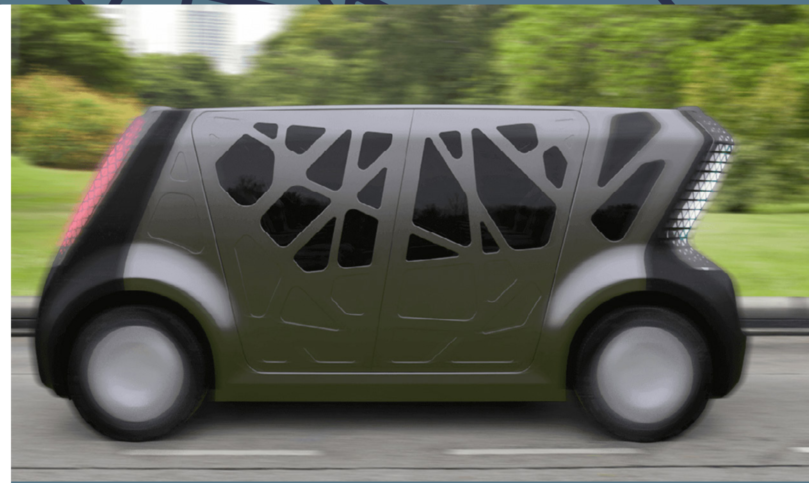


Figure 9. SEM1 BIW joining methodologies



Summary
WorldAutoSteel's SEM concept designs for future autonomous vehicle body structures demonstrate the scale and breadth of AHSS material grades presently available. The combination of material grade, gauge thickness and manufacturing processes, such as Tailor Welded Blanks, hydroforming, roll forming and roll stamping, has resulted in a cost- and weight-efficient body design, which achieves very good safety and crashworthiness performance and minimizes life cycle emissions to align with net zero emissions targets.

Relatively conventional body structure joining and manufacturing methods have been applied, which are ideally suited for high-volume global vehicle manufacturing. With some regional variations in AHSS grade availability, an alternative BIW material utilisation approach was demonstrated with similar cost and performance expected. Despite the futuristic design intention of the Steel E-Motive autonomous vehicle, the material grades described in this publication are currently commercially available from different WorldAutoSteel member companies.

The latest AHSS grades are expected to serve the future demands from the automotive industry – steel continues to offer a cost-effective and sustainable solution for body structures. With 66% of SEM's grades showing strength levels of 1000MPa to 2000MPa, it's clear that AHSS application can deliver a weight-efficient solution for crash load management and protection structures. The multi-part fabricated assembly approach provides the manufacturing flexibilities required by OEMs to manage production volumes and vehicle derivatives. As OEMs seek solutions for enhanced part formability coupled with ultra-high-strength, AHSS products such as Press-Hardened Steel and cold-stamped 3rd generation grades will grow.

WorldAutoSteel provides comprehensive guidelines and information on the application of AHSS via its online AHSS Application Guidelines. These can be accessed via **https://ahssinsights.org/.**

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