Automobile manufacturers are using a number of methods to improve fuel economy. Some of the most effective methods to achieve this are engine downsizing, turbo systems, electrification, aerodynamics, and lightweighting. When trying to lightweight a vehicle, a number of OEMs will implement aluminum extrusions, and for good reason. Aluminum extrusions are an efficient technology delivering low mass, structural rigidity, high thermal conductivity, and leak-free fluid transfer. For example, the Ford F-150 pickup, the world’s number one best selling vehicle, utilizes an all-aluminum design, which incorporates around 70 lbs (32 kg) of extrusions in order to create a safe and efficient body structure.

In recent years, the conversation has heated up on electrification. Will it gain market acceptance and, if so, how will it affect the material selection? Logically, range-limited vehicles will benefit most from lightweight structures, yet because of the expensive batteries and related operating systems, automotive OEMs need to carefully manage costs.

OEMs must also strike a balance on their investments between electric vehicles (EVs) of tomorrow and the profitable internal combustion engine (ICE) powertrains of today. Most EVs to date are not profitable, yet the growth in these vehicles seems inevitable. Some of the automotive components and structures are specific to one kind of powertrain, such as the battery box to an EV. However, many components are ubiquitous across different types of powertrains, as they provide lightweight structural benefits in areas such as the rockers, cross members, subframe, and roof.

The Aluminum Extruders Council (AEC) has an automotive team focused on extrusion industry oversight and promotion. The team pools its resources to research automotive technology and produce promotional materials that will assist in the design and development of automotive systems using extrusions. In collaboration with the automotive team, Mayflower Consulting was hired to lead a study focused on automotive applications, with the aim of providing insights on competitive and complementary technologies. The research covered automotive engineering performance, materials, manufacturing processes, the value proposition of extrusions, and applications already in production today. The market research examined a number of different systems across the vehicle. A few major systems were down-selected, and a demonstrator website was created to promote the use of extrusions.

**Interactive Automotive Guide**

The Interactive Guide is available on the AEC website (aec.org/autosolutions), providing visitors with the ability to learn more about the potential for extrusions in automotive systems. When the webpage opens, an interactive demonstrator is shown (Figure 1), listing various systems of the vehicle, including the roof headers, subframe, battery box, cross members, rockers, and more. When the user selects a system to explore, the website offers three tabs—Overview, Materials & Performance, and Success Stories. The Overview provides a general look at the system selected, describing its general size, weight, and purpose within the vehicle. Under Materials & Performance, the general performance characteristics required by the system are addressed, along with information on the kinds of aluminum alloys that can be used and the mechanical properties that enable them to meet the required characteristics of the system. Success stories provide real-world examples of aluminum extrusions used in the system. These examples illustrate the design and performance of the extruded part and show that they are more than just concepts. They are actual components found on a number of production vehicles.

This paper presents the kinds of valuable information that can be found within the Interactive Guide on the AEC website, with a focus on EV battery boxes, subframes, and rockers.

**EV Battery Boxes**: The growth of electrification brings many new challenges, one of which is to design and manufacture a robust battery box or housing. An efficient battery housing has many attributes that aid passenger and battery safety and assist in thermal management, while protecting the battery from the harsh environment under the vehicle and during an accident. In general, the battery box consists of four primary structural pieces: top cover, bottom cover, internal structure, and side impact crash protection structure (Figure 2). The system must be produced in accordance with the financial and weight constraints of the vehicle.

The battery system (including the battery, box, and other components) is enormous at around 2 m x 1.4 m and weighing as much as 700 kg, representing 22-27% of total vehicle weight. At a minimum, this mass needs to be reduced in accordance with financial and weight constraints. The Overview provides a general look at the system selected, describing its general size, weight, and purpose within the vehicle. Under Materials & Performance, the general performance characteristics required by the system are addressed, along with information on the kinds of aluminum alloys that can be used and the mechanical properties that enable them to meet the required characteristics of the system. Success stories provide real-world examples of aluminum extrusions used in the system. These examples illustrate the design and performance of the extruded part and show that they are more than just concepts. They are actual components found on a number of production vehicles.

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to remain stable during vehicle performance. In the best designs, the battery and enclosure greatly enhance vehicle structure and ability to absorb crash energy. One of Elon Musk’s messages in the recent Tesla Battery Day was about the elimination of duplicate material in and around the batteries. To perform under these requirements, it is imperative to select the best materials and manufacturing processes for the housing and structure because it makes up as much as 20% of the cost and the weight of the battery system.

Aluminum extrusions can be designed with an efficient geometry offering multiple functions, including: crash energy absorption, torsional stiffness, considerable strength with minimal weight, leak-free fluid transfer through structural members, long lengths, and straightness with stringent profile tolerances. The Interactive Guide offers a long list of these attributes that make extrusions ideal for the battery box. This includes low tooling cost, quick time to market, excellent thermal management characteristics, corrosion resistance, and low density. The prominent alloys are included too, covering the popular 6005A and 6061 as well as the stronger 6082-T6.

Finally, when an extruder meets a new OEM prospect, the conversation is much easier when there are prior examples of commercial success. Even though EVs have only recently started becoming mainstream, there are already great examples on the use of extrusions in battery boxes for the reasons stated. One example is the Mercedes EQC, which takes advantage of many attributes of aluminum extrusions for the battery and vehicle safety (Figure 3).

Subframes: The subframe is the structure that supports the axle, suspension, and powertrain. For internal combustion engines, it is often located in the front and is referred to as the engine cradle, or in some cases, the K-frame. For electric vehicles, it wraps around the motor housings, providing mount support, and protects the battery in a frontal crash. In either case, the subframe performs a critical role in the stability and the ride quality, which ensure the vehicle dynamics and safety needed to meet customer expectations.

Subframes are subject to considerable mechanical stresses, and being located near the ground, environmental conditions as well. They are sized according to the vehicle and the powertrain, and for a mid-size crossover or sedan, the weight is 14-35 kg, depending on the material and the size. There may be one in the front, one in the rear, or both.

Due to their versatility, extrusions can be designed and implemented in subframes in multiple different ways. The Chevy Impala GM X211 program developed a front subframe using only aluminum extrusions (Figure 4). Most sections were 6061 alloy, with a couple being 6063. Multiple tempers have been utilized to maximize product performance. Meanwhile, the Audi A5 and S5 vehicles implement a hybrid design, which incorporates aluminum vacu-

um die castings on the corner nodes that are connected by extrusions (Figure 5).

Because the subframe is below the floor of the vehicle, it is constantly bombarded with rocks and debris and is exposed to road salts. Therefore, corrosion protection is a key attribute to a long-lasting structure. Aluminum naturally forms an aluminum oxide coating, which protects well against environmental conditions. Not every material performs so well, with steel structures being prone to rust, especially in regions with heavy snow or rain.

Most common subframes are made of high strength steels. Therefore, the most popular alloy for constructing an aluminum extrusion-based subframe is high strength
6082. Stronger alloys are available, and would lead to more weight reduction. However, the auto manufacturer is often seeking the lowest cost means to achieve success in each system. One aspect to achieving low cost is a low cost base alloy; another is to select an alloy that is produced by many suppliers as the competition brings robust capabilities in processing and integration.

Extruders can tailor the alloy chemistry and processing to meet strength, cost, and grain structure requirements. The microstructure is determined by both chemistry and extrusion process parameters, especially extrusion temperature and quench. This is particularly critical to manage extrusion straightness, twist, and bowing on long components like rockers, yet also on the EV battery boxes.

**Rockers:** A popular application for long, straight and multi-hollow extrusions is within the rocker. Located below the door, the rocker plays an important structural role, providing body stiffness and side impact protection. An example of an extruded aluminum rocker is shown in Figure 6. The use of extrusions in the rocker will likely grow with electric vehicles, as the side protection is also critical for preventing battery damage as well as providing passenger protection.

**Conclusion**

The AEC Interactive Guide is now live. The website covers a number of automotive applications that utilize aluminum extrusions, from rockers and cross members to EV battery packs. The site provides a space to learn about the growing applications for aluminum extrusions and how they bring value to the automotive manufacturer. With a close collaboration between the OEMs, Tier 1 suppliers, and aluminum extruders, there will be many more extrusion success stories in the years to come.

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**New Interactive Website for Automotive Engineers**

- Extrusion Applications
- Technical Details
- Case Examples

Explore what’s possible with Aluminum Extrusions!

[Image: AEC.org/AutoSolutions]