Alumobility Introduces a New Generation of Aluminum Doors

By Andrew Halonen, Mayflower Consulting LLC

Anyone who works with aluminum or other materials understands how difficult it is to introduce a new material to the automotive industry and gain market acceptance. The typical timeframe for the acceptance of a new material in automotive may be five to seven years, assuming the automaker is dedicated to the effort and providing sufficient resources for its development. Without that push from the automaker, achieving market acceptance can take even longer. For example, many suppliers of metal matrix composites have been trying to get into the automotive market for 20 years or more, without achieving meaningful commercial success. It is said, "No one wants to be first, but everyone is lined up around the block to be second."

Alumobility is a research and development group founded by Novelis and Constellium. Designed to be a global ecosystem of leading aluminum and downstream technology partners, the group is combating the challenge surrounding the adoption of aluminum by working together to explore and expand the opportunities for the use of aluminum sheet products for mobility applications, namely passenger vehicles.[1]

Recently, Alumobility hosted a webinar titled, "Fourth generation aluminum doors: Affordable, lightweight and built for a circular economy."[2] The presentation discussed the challenges of car door engineering, looked at the history of aluminum use in car doors, and highlighted the group's recent study, which presents a fourth generation aluminum door design. The new design is aimed at making aluminum more attractive for car door applications.

Car Door Engineering

A passenger car door is comprised of the frame and structure, internal hardware, and trim (Figure 1). The structural portion of the door, which was the focus of Alumobility's study, is generally metallic and makes up to 80% of the door weight and cost. It includes the inner and outer panels, a frame around the window (if present), and impact intrusion beam. These components are generally comprised of sheet metal that has been stamped or roll formed into the complex shapes required. Stamping and roll forming are implemented as they are able to achieve low cost, high volume production.

Car doors also have specific requirements regarding both static load and crash load (Figure 2). Static load includes four use cases that need to be addressed, including door sagging (the load on the door when it is open), wind overload (the impact of a strong wind hitting the open door), waistline stiffness, and frame stiffness. There are also two crash load cases, which include side impact (when the vehicle is struck from the side) and door crush (when the door is impacted during a front-end crash). In door crush design, the small offset rigid barrier (SORB) is becoming increasingly important due to the high number of fatalities being caused by frontal crashes that miss the front bumper crash management system.

Lightweight doors provide a number of structural and design advantages, such as reducing static load and enabling car companies to build more technologies into the doors. For example, in autonomous vehicles, the doors may have a mechanism that opens them automatically. A lightweight door can be outfitted with a smaller, lighter weight mechanism that is easier to package, saving room for passengers and their luggage. Aluminum is an excellent material for providing such lightweight designs, due to its strength-to-weight ratio and ability to achieve high stiffness.

History of Car Door Development

For decades, steel has been the baseline material for most car applications, from body-in-white structures to

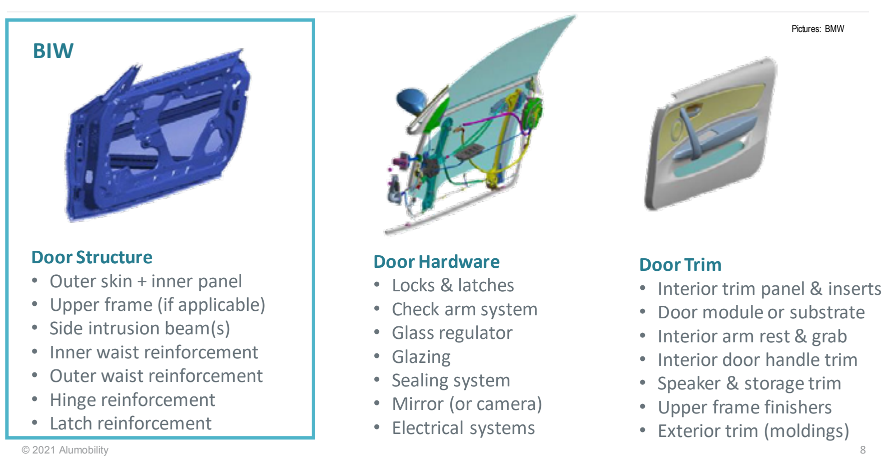

Figure 1. Key areas of an aluminum car door design. (Source: Alumobility.)

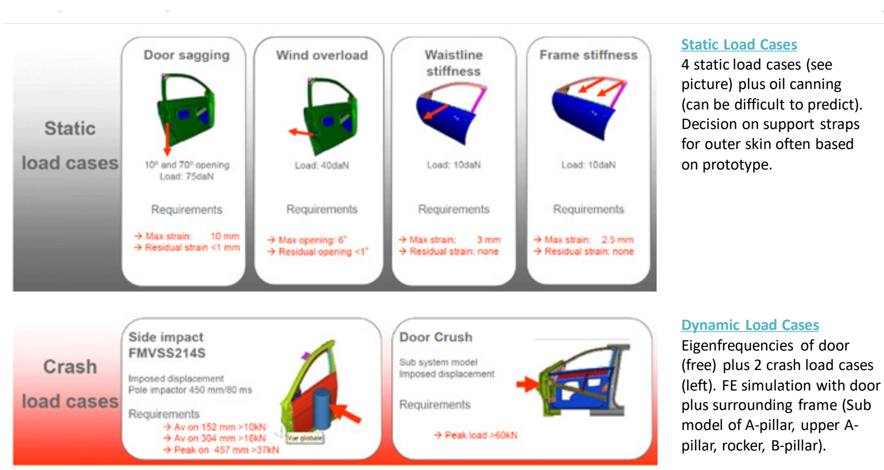

Figure 2. Static and crash load cases on car doors. (Source: Alumobility.)

closures (including doors, hoods, etc.), as well as subframes and suspension parts. The National Academies Press reported that, in 2015, steel dominated the car door market.[3] Based on weight, steel was more common than aluminum in car doors by a ratio of almost 40:1. However, aluminum doors (along with roofs) are expected to grow, with the ratio of steel to aluminum doors (by weight) reaching 6:1 by 2025.

In their presentation, Alumobility further expanded on the history of aluminum use in car doors. As far back as 1995, aluminum has been used in car doors for low-volume sedans, primarily European premium car brands. However, this usage is not noted in U.S. government reports, probably because there was not a significant enough volume for it to be noticed.

Despite the sluggish start to aluminum doors, the application is rapidly expanding. Alumobility estimated 500,000 aluminum doors were produced by 2012, which grew to 3.5 million doors in 2019. According to a report from Ducker Research,[4] 21% of vehicles had aluminum doors by 2020, at an average of 14.1 lbs (6.4 kg) per vehicle totaling 270 million lbs (122 million kg) of aluminum. This massive volume increase has been significantly helped by the Ford F-150, the number one selling vehicle in America. Other major car programs have also started implementing aluminum doors, including the popular T1XX programs from General Motors, which include the high-volume Silverado pickup and large SUVs, such as the Suburban, Tahoe, Yukon, and Escalade. In addition, BMW's two large SUVs, the X5 and X7, use aluminum for front and rear doors. By 2026, the aluminum penetration in front and rear doors is expected to reach 30% of all vehicles, representing a gross shipment of 525 million lbs (238 million kg) of aluminum sheet.

Figure 3. Four generations of aluminum doors. (Source: Alumobility.)

Concept	Steel Reference	Al Production Today	State-of-the-Art	Lightest
Description	Series Product	Standard alloys	Uni-alloy 6xxx door	6xxx door with 7xxx SIB
Outer panel	CR180BH 0.65mm	Al6-Out 0.9mm	Al6-Out 0.9mm	Al6-Out 0.9mm
Inner panel	CR4-GI40 0.7mm	5182 1.1mm	6016 HF* 1.1mm	6016 HF* 1.0mm
Window frame	CR2-GI40	5182	6016 RW**	6016 RW**
Reinforcements	CR300LA	6111 (>250 MPa)	6x HS PFAA*** (>300 MPa)	6x HS PFAA*** (>300 MPa)
Side Impact Beam	CR440Y780T DP	Hot formed steel	6x HS PFAA*** (>300 MPa)	7075 HF**** (>500 MPa)
Window frame	1 piece	1 piece	3 pieces	1 piece
Crash Tube / max load in door crush	Incl. / 35kN	Incl. / 64 kN	Incl. / 70 kN	Without / 34 kN
Weight [kg]	**17.86**	**10.23kg**	**9.74kg**	**8.99kg**
Part count [>50g]	13	11	14	10
Percentage weight saved		42.7%	45.5%	49.7%
Value In Use (VIU)	0	<€3/kgs	€3/kgs	€3.39/kgs

© 2021 Alumobility

* HF = High Forming
*** HS PFAA = High Strength Post Form Artificially Aged
** RW = (Laser) Remote Weldable
**** HF = Hot forming with PFAA

33

Table I. A comparison of the base-line steel door with the fourth generation lightweight aluminum door (Source: Alumobility.)

As aluminum doors grow in use, their design has also evolved. Alumobility documented four generations of doors (Figure 3). The first generation design, which dates between 1995-2005, was used on premium sports cars. Made using a combination of sheet, thin wall castings, and extrusions, the first generation had a high cost and low usage. Generation two (up to 2010) improved the quality and reduced the complexity of the aluminum door by replacing castings with sheet products. Generation three, which extended through 2020, focused on achieving high volume production. The aluminum door design is very sheet intensive, featuring reinforcements that were also stamped from sheet metal. The design aimed for the lowest cost and best quality.

The fourth generation design was developed by Alumobility as part of a study. Aiming for 2021 and beyond, the new aluminum door is also comprised of sheet products that are stamped or roll-formed to minimize costs and achieve high volume production. However, the design brings more innovation through the use of high performance materials that allow for thinner gauges, reduced weight, and advanced metal joining technologies.

Fourth Generation Aluminum Door

When designing the new generation aluminum door, Alumobility used a high volume steel door from a mid-size SUV as its reference point, since this is a widely growing vehicle segment. In converting the steel door to aluminum, the team took into account not only the structural and performance factors of the door, but also its material cost and manufacturability. A comparison of the steel baseline door and the new generation aluminum door is presented in Table I.

The new, fourth generation aluminum door builds upon improvements made in the previous generation, but weighs 1.24 kg less. The new door reduces the part count, bringing it down to only ten components. It replaces the use of 5182 alloy in the frame (sash) with a stronger 6016 alloy. In addition, a high strength 7075 alloy was used in the side impact beam and reinforcement components, resulting in a 0.49 kg weight reduction from the generation three door. However, Alumobility noted that the use of 7000 series alloys are pretty exotic and is only used in a few cars. It should also be noted that the design team chose not to use an extruded impact beam for the design due to the need to flatten the ends for joining. At the production volumes required, stampings were more cost effective.

Alumobility reported that the new aluminum door weighs only 10.23 kg, a substantial reduction from the 17.86 kg steel door. It is also able to meet or exceed the safety and customer attributes provided by the steel door. In addition, the tooling estimate for the new aluminum door for a mid-sized SUV with a production rate of 300,000 vehicles is estimated to be €12.37 million, or 15% more than a steel door. The additional cost is primarily attributed to the use of laser welding. However, when considering a seven year long vehicle program, this is not a significant expense. The cost premium is impressively low at <€3/kg ($1.36/lb) for the current third generation aluminum door, with the fourth generation door increasing to only €3.39/kg ($1.54/lb). Considering the impressive amount of lightweighting achieved, this is very cost effective.

Conclusion

Once a material establishes a foothold in the automotive sector, a push for growth follows. With each iteration, the material solution is optimized in design, cost, and weight. Aluminum sheet appears to have found a sweet spot in closures applications, such as aluminum doors, as it is comparable in performance to bake hardened steels, while also providing significant weight reduction and better corrosion resistance. Alumobility's introduction of a new generation aluminum door represents yet another use-case for implementing aluminum in vehicles. This provides a compelling business case for OEMs to choose the reduced weight option.

As the innovation continues, new forming and joining methods will become faster and more versatile, and at reduced costs. For example, friction stir welding (FSW) presents an automated process capable of joining different materials. Another such innovation is the use of tailor welded blanks being developed and sold by TWB Company.[5] With tailor welded blanks, stamp-formed components like car doors can selectively incorporate thicker sheet in specific areas that need additional strength, such as the door hinge or latch. Because the thicker sheet is only used where needed, the cost is reduced. With such innovative processes and alloy optimizations, it is likely that aluminum doors will be implemented on the majority of vehicles in the near future.

References

1. Svendsen, Andrea, "Alumobility Drives Automotive Innovation: Novelis and Constellium Collaborate to Develop Aluminum Ecosystem," *Light Metal Age*, June 22, 2021, www.lightmetalage.com/news/industry-news/automotive/alumobility-drives-automotive-innovation.

2. "Aluminum Doors Open New Possibilities," Alumobility, alumobility.com/technical-solutions/aluminum-doors-open-new-possibilities.

3. *Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles*, National Research Council of the National Academies, 2015, p. 257, http://nap.edu/21744.

4. "North American Light Vehicle Aluminum Content and Outlook," DuckerFrontier, August 2020, www.drivealuminum.org/research-resources/duckerfrontier-north-american-light-vehicle-aluminum-content-and-outlook-august-2020.

5. "Aluminum Tailor Welded Blanks," TWB Company, www.twbcompany.com/applications/#filter=.aluminum-tailor-welded-blanks. ■