Applications – Car body – Hang-on parts

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3 Hang-on parts

3.1 Boot lids and liftgates

The boot lid (UK) or decklid (US) is the panel that covers the boot (or trunk) of an automobile. It enables access to the main luggage compartment. A hinge allows the boot lid to be raised, while devices such as springs or gas cylinders hold it up in the open position.

Jaguar XJ (X351), a car model with an aluminium boot lid

(Photo: Jaguar)

In principle, boot lids have to fulfil similar requirements and are subject to the same design guidelines as bonnets. However, aluminium sheets are used much less for boot lids than for bonnets. The main reason is that the “value” of weight saved in the rear of the car is significantly lower than in the front because of the aim for a 50:50 axle load distribution. In many cases, automobile engineers are even shifting mass (e.g. batteries) towards the back in order to achieve a more balanced axle weight distribution.

Consequently, aluminium boot lids are mainly used for car models with an all-aluminium body structure. But there are nevertheless a few (mixed material design) upper car models which use an aluminium boot lid for weight reduction. When substituting aluminium for steel in a boot lid, weight savings of about 50% can be achieved. As an example, the boot lid shown below (weight 8.6 kg) - which was designed for the Ford P2000 vehicle - represents a weight reduction of 5.4 kg (53%) compared to an equivalent steel design. The alloy AA 6022-T4, aged to T6 during paint bake process, was applied. The thickness of the outer and inner panel of the bonnet and the boot lid was similar (0.85 mm).

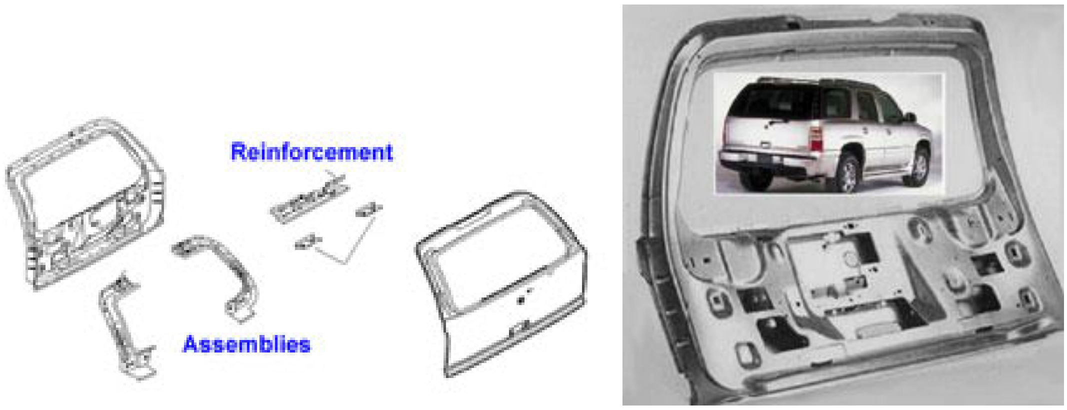
Boot lid of the Ford P2000 vehicle produced using the Multicone® design for the inner panel

An interesting example is the boot lid shown below which is made from the alloy TopForm® SPF. This is an AlMgMn alloy optimized for the superplastic forming process with a composition corresponding to the alloy EN-AW 5083. The alloy offers an ultra-fine grain structure as a result of special processing conditions during casting, rolling and heat treatment.

Superplastically formed boot lid for the Cadillac STS made from AMAG TopForm® SPF (Photo: AMAG)

More important is the application of aluminium sheets for liftgates (or rear hatches) and tailgates, i.e. the doors or “gates” at the back of SUVs, hatchbacks, station wagons and similar type of vehicles. Liftgates and rear hatches are hinged at the top and open upwards, tailgates are lateral opening doors which are hinged at the left or right side. They greatly benefit from a reduced weight due to easier handling. In addition, a reduced weight can translate into significantly lower rear axle loads (as these panels overhang the rear axle) and hence additional seating capacity.

An early example of an aluminium liftgate is the GMT 830 liftgate. It was an all-aluminium design using EN-AW 6111-T4PD for the outer panel, EN-AW 6111-T4P for the reinforcements and EN-AW 5182-O for the inner panel. The aluminium liftgate was stamped using conventional press tools. The gauge of the outer panel was selected to meet the denting and oil-canning requirements. The aluminium liftgate was assembled using resistance spot welding and hemming. Coated steel nuts were used for hinge and latch attachments.



Aluminium liftgate of the GMT830

Audi Q5, an SUV equipped with an aluminium liftgate

(Photo: Audi)

Aluminium liftgate for the Saab 9-3 station wagon

(Photo: Hydro Rolled Aluminium Products)

For the outer panel of the Saab 9-3 liftgate, the alloy EN AW-6016 has been used (t = 1.0 mm). The inner panel is made from the alloy Hydro 5182-M ssf (t = 1.2 mm), a special quality of the annealed O-temper EN AW-5182 ("stretcher-strain poor and/or stretcher-strain free"). In the "stretcher-strain free" condition, the formation of stretcher strain marks of the type A is suppressed by a small pre-deformation of the annealed sheet (at expense of the remaining formability). However, as soon as the strain level increases above 5 to 7 %, the fine striations of the Lüders lines of type B with a surface roughness depth $< 10\ \mu m$ cannot be avoided. Therefore, "stretcher-strain free" AlMg alloy qualities have not found significant practical application.

An interesting lightweight design variant exhibits the tailgate of the VW Lupo 3L (produced 1999 – 2005), a special edition made with the intention to consume only 3 l of fuel per 100 km. The solution chosen for the tailgate included an integral magnesium inner part and an aluminium outer panel (as well as aluminium lock reinforcements) with a weight of 5.4 kg (compared to 10.5 kg for the steel solution). The aluminium outer panel is flanged over the magnesium inner part. In addition, adhesive flange bonding is used for strength and insulation. To avoid any potential of contact corrosion, the magnesium die casting is coated before assembly.

A cost-efficient lightweighting option is also the application of aluminium castings for the frames of back windows (see below).

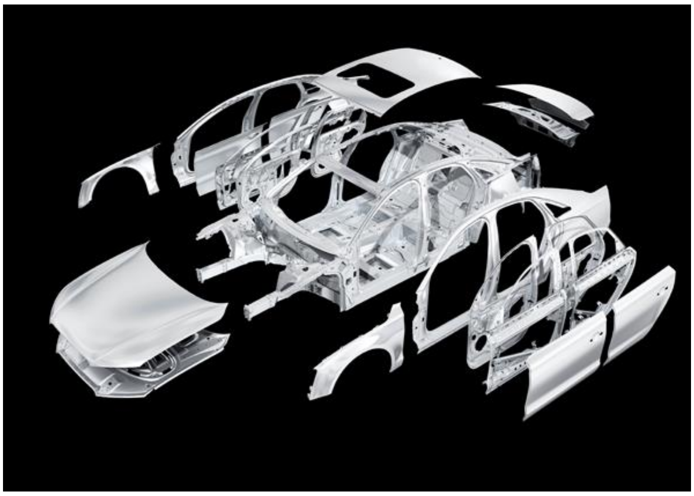
Cast aluminium frame for a back window (alloy EN-AC-AlSi12Cu1(Fe))

(Photo: GF Automotive)

3.2 Wings

Wings (UK) or fenders (US) denote the car body part that frames a wheel well (the fender underside). Its primary purpose is to prevent sand, mud, rocks, liquids, and other road spray from being thrown into the air by the rotating tire.

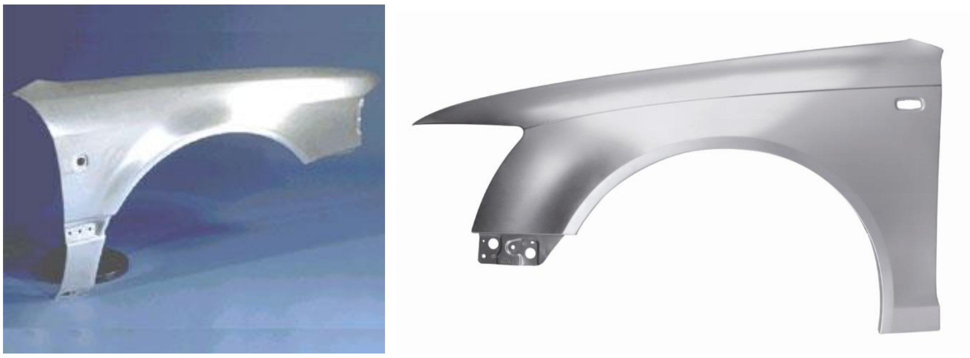
The term “wing” usually refers only to the panels over the front wheel arches since in modern cars, the rear “wings” are rather an integral part of the car’s side wall. The industry changed from rear wings bolted onto the quarter panel (a body panel which extends between the rear door and the trunk) to an enlarged quarter panel that fulfilled both functions and ultimately to a one-piece side wall. Today’s state-of-the-art is a one-piece side wall; the quarter panel is used in those cases where the production of a one-piece side wall is not feasible for technical reasons.



All-aluminium body structure of the Audi A8 with a one-piece side wall and a separate front wing

(Photo: Audi)

In general, wings are relatively simple components and a conversion from steel to aluminium does not present any difficulties.



Aluminium wings (Photos: Novelis)

The basic requirements for aluminium wings are largely identical with those for the outer panels of bonnets or boot lids, i.e.:

- stiffness - determined by design and sheet thickness (generally 1.4 x steel sheet thickness),
- buckling resistance - determined by sheet thickness, yield strength and design,
- dynamic denting (stone chipping) - determined by sheet thickness and yield strength,
- surface quality - determined by alloy type (preferably of the AlMgSi series), surface roughness and microstructure, and
- small hemming radius.

Today's standard aluminium alloys for outer body applications of the EN-AW 6xxx system fulfil all the requirements for standard wing designs. The resulting weight reduction compared to steel is normally slightly more than 50 %, i.e. the substitution of steel by aluminium for the wings offers attractive weight reduction possibilities in the front of the car. However, the market penetration of aluminium for wings is significantly lower than for bonnets. The main reason is that in many cases, plastic or fibre reinforced plastic wing panels are used. The advantage of plastic materials is the lower sensitiveness of plastics against minor parking damage (e.g. scratches and small dents).

But there are also car models where wings of highly complex shapes are required. An interesting solution for these special cases offers the superplastic forming technology.

Bentley Continental GT, the complex shape of this wing is realized by superplastic forming using the alloy AMAG TopForm® SPF

(Photo: AMAG)

3.3 Doors

The door allows entering and exiting the vehicle. The doors can be opened manually, or electrically powered. A conventional car door is hinged at its front-facing edge, allowing the door to swing outward from the car body. This type of door has the advantage that if it is opened during forward motion of the vehicle, the wind resistance will work against the opening door, and will effectively force its closure.

But depending on the type of car, there are also other door concepts in use:

Rear-hinged doors make entering and exiting the vehicle much easier. However safety concerns prevent the use of “suicide doors” today. On modern vehicles, the exceptions are rear-hinged back doors in combination with front-hinged front doors, mainly on chauffeur-driven cars, taxis and MPVs.

Rear-hinged doors on a Rolls Royce Phantom, its aluminium space frame is the largest of its kind ever built

(Photo: Rolls Royce)

Scissor doors are automobile doors that rotate vertically at a fixed hinge at the front of the door, rather than outwardly as with a conventional door. This type of doors is used on some exclusive sports cars (e.g. some Lamborghini models).

Scissor doors on the Lamborghini Countach, produced 1974 – 1990 with an aluminium skin over a steel tube space frame

(Photo: Lamborghini)

Butterfly doors are a type of door also seen on high-performance cars (e.g. the McLaren F1 supersportscar). They are similar to scissor doors, but while scissor doors move up, butterfly doors also move outwards, which makes for easier entry/exit at the expense of saving space. Gull-wing door describe car doors hinged at the roof rather than the side. They are found only on selected sports car models.

Gull-wing doors Mercedes-Benz SLS AMG roadster, the doors include superplastically formed outer and inner panels made from the alloy AMAG TopForm® SPF

(Photo: Daimler)

Sliding doors open by sliding (usually horizontally), whereby the doors are either mounted on or suspended from a track. Sliding doors are most commonly used for minibuses (MPVs) to provide a large entrance or exit for passengers or without obstructing the pavement. They are also often used on the side of commercial vans as this allows a large opening for cargo to be loaded and unloaded without obstructing access.

However, the car door is not a simple hang-on panel but rather a structural module which fulfils many different functions. Basically, the door consists of an outer panel supported by an inner structural element where various additional components are attached. Furthermore, modern car doors usually include a reinforcing element ("side impact beam") which protects the driver and passengers in case of a side impact, e.g. when smaller cars are struck by a larger SUV.

The door shell, the most visible component of a car door, holds all door parts together. The most important additional parts integrated into the door are:

- **Hinges:** The hinges connect the door to the body structure, allow opening and closing of the door and keep the door in the necessary position to close properly.
- **Door handle and lock:** These parts allow the door to close securely and prevent it from opening. There are a variety of car door locking systems. Newer cars contain a power lock feature that allows drivers to remotely lock all doors. The door handles are on the inside and outside of the car door.
- **Windows and window regulator:** Vehicle doors have generally windows and most of these may be opened to various extents. Generally, car door windows retract downwards into the body of the doors. The window regulator is the mechanism found inside the car door that raises and lowers the window glass. The windows are opened either with a manual crank, or switchable electrical motor.

In addition, there is in general an interior door panel which is an important styling component for the interior, but also contributes to the functionality and ergonomics of the car. It holds various interior parts like the interior door handles, armrests and/or storage trays, switches, and lights. The door body may also house noise dampening mats, electronic systems like the window controls and locking mechanism, loudspeakers or airbags as an additional protection in case of a side impact, etc.

3.3.1 Aluminium door designs

Doors are quite different in design from one manufacturer to the next and also from one car model to another. Traditionally, the car door is built from steel; an outer panel and an inner panel which also serves as a mounting plate for the various attachments. On the other hand, doors are also most interesting car parts for lightweighting:

- The total weight reduction potential of two or four doors is quite significant.
- Lighter doors offer additional advantages (easier opening and closing, less sturdy hinge design, etc.).

Therefore the application of aluminium has been on the door lightweighting agenda for a long time. Compared to other hang-on parts, however, doors offer many different possibilities for lightweight aluminium concepts, both in the form of all-aluminium and mixed material designs. In general, a differentiation between the outer panel and the inner structure is necessary. The steel outer panel can be easily replaced by an aluminium sheet panel. An interesting example is the door of the Land Rover Defender which is produced since 1948 with an aluminium outer panel on a steel inner frame. But there are also examples of car doors with a plastic outer door panel (e.g. the Smart door) and, for extreme lightweighting, outer door panels are made from carbon fibre reinforced composites.

Land Rover Defender, the doors include an aluminium outer panel on a steel inner frame

(Photo: Jaguar Land Rover)

The new Honda Acura RLX exhibits a modern aluminium/steel door design. In order to join the dissimilar metals, different technologies were applied to prevent contact corrosion and thermal deformation.
Honda newly developed three technologies that enabled adoption of aluminium for the outer door panel:

- adoption of the '3D Lock Seam' structure, where the steel panel and aluminium panel are layered and hemmed together twice
- use of a corrosion-protected steel for the inner panel, complete filling of the gap with the adhesive and optimized sealant application
- utilization of an adhesive with a low elastic modulus (better ability to 'stretch').

The mixed material design reduces the door panel weight by approximately 17% compared to the conventional all-steel door panel. In addition, weight reduction at the outer side of the vehicle body shifts the centre of gravity further toward the centre of the vehicle, contributing to improved stability in vehicle manoeuvring.

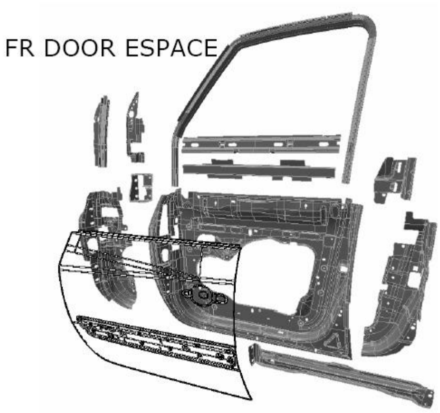
Door of the 2013 Honda Acura RLX with an aluminium outer and a steel inner panel (Photo: Honda)

For the inner (supporting) structure, there are even more design options. Apart from pressed aluminium (and steel) panels, also formed aluminium extrusions (for assembled inner structures) and thin-walled aluminium and magnesium castings can be applied. The application of die-cast inner structures or assembled structural modules (consisting of extruded or extruded and cast components) is most interesting for small to medium production volumes. The advantage of aluminium extrusions and castings is the possibility to vary the wall thickness according to the local loads as well as their ability for part integration. But also in a pure sheet design, a variation of the material thickness is possible by the application of aluminium tailor welded blanks.

a) Sheet design

Steel doors are traditionally constructed using stamped sheet panels, a design concept that can be realized in aluminium too. For large production volumes, sheet shell doors are always the most cost-effective solution.

The simplest design variant consists of an outer and an inner panel, but there are also design concepts where the window frame is a separate parts and/or the inner door is an assembled structure. In addition to the side impact beam, there are often also some reinforcement elements in the load-critical areas, e.g. at the hinge and the lock side.



Front door of the Renault Espace, a traditional sheet design concept which has been realized in aluminium

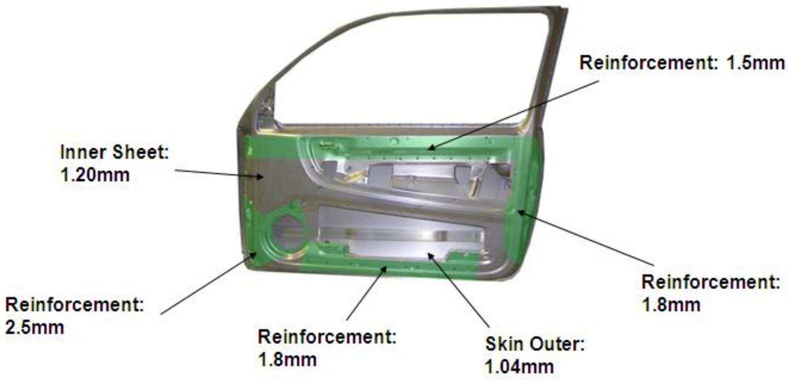
(Source: Renault)

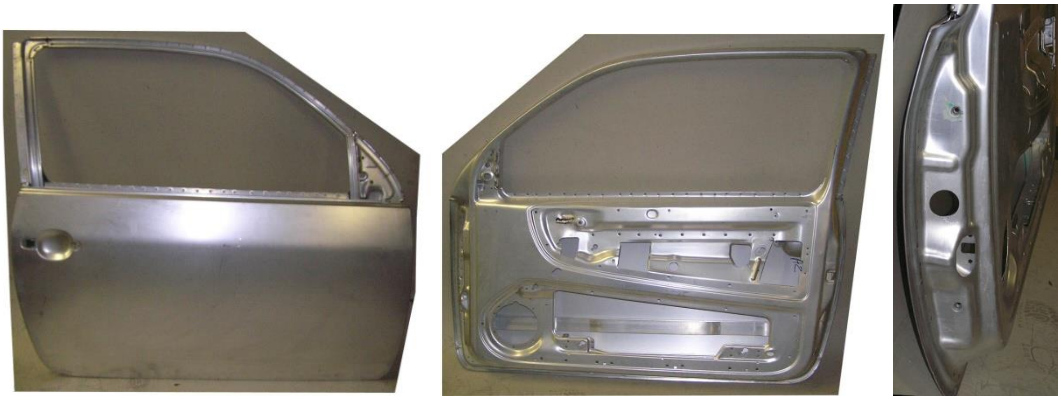
Early examples for aluminium sheet doors realized using the traditional steel design concept are the front doors of the Renault Espace and the Renault Vel Satis. The only adaptation to the new material is the window frame which is a properly bent extruded aluminium section. Compared to a steel door, the aluminium door shows a substantial weight reduction (37 %). For the outer panel, the AlMgSi alloy EN AW-6016 is used, the alloy for the inner panel is EN AW-5182.

Front door of the Renault Vel Satis with aluminium sheet outer and inner panels and an extruded aluminium section for the window frame

(Photo: Novelis)

An example of an aluminium sheet shell concept without a separate window frame is the door of the Audi A2. The outer panel has been produced from the alloy EN AW-6016 (Anticorodal®-121), the inner panel and the reinforcements from Ecodal®-608 (EN AW-6181A).





Audi A2 front door, an aluminium two sheet shell design

(Photo: Novelis)

A technical limitation in early aluminium sheet shell door design proved to be the limited formability of the standard aluminium car body sheet alloys compared to that of deep drawing steel grades. In particular for doors of upper class vehicles, a large drawing depth is required for the inner panels. Using standard stamping procedures, the consistent realization of such high drawing depths presents some problems with the available standard car body aluminium alloys in large series production. Nevertheless, the fabrication of aluminium inner door panels with larger drawing depths is possible, but asks for more complex and closely controlled (and therefore more expensive) stamping procedures.

Aluminium door for the BMW 6xx series models with an aluminium outer (EN AW-6016) and inner (EN AW-5182) panel

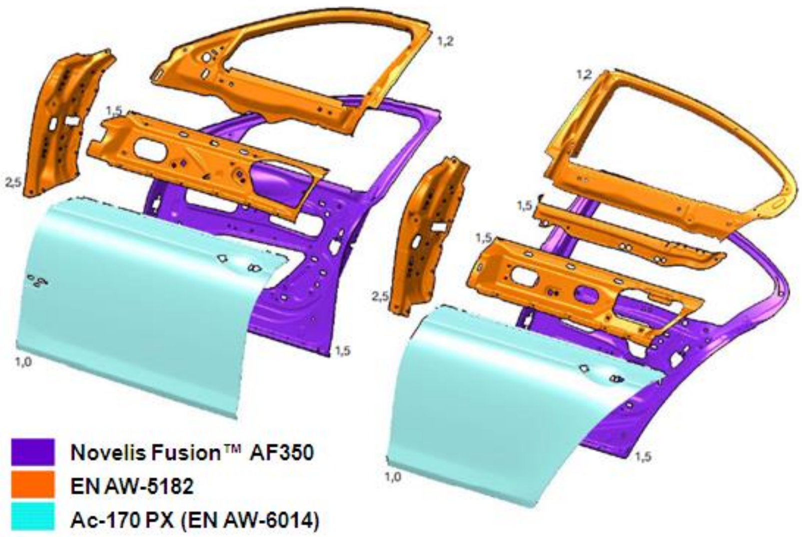
(Photo: Novelis)

An alternative, but also expensive option is the application of special forming methods, e.g. superplastic forming. The inner front door of the Maybach shown below has been made from superplastically formable EN AW-5083 (Formall®-545) using a forming temperature of 515 °C. The initial sheet thickness was 1.6 mm in case of the inner door panel and 3.0 mm for the reinforcement panel. The forming time was about 20 min.

Inner door panel and hinge reinforcement of the Maybach luxury car (produced 2002 – 2009)

(Photos: FormTec)

Consequently, the introduction of weight-optimized aluminium sheet shell door concepts was only possible with the development of the Novelis Fusion™ technology. It allows the cost-effective production of multi-layer aluminium sheet materials and – provided that a proper alloy combination is selected − aluminium sheet materials with significantly improved forming properties. The Novelis Fusion™ alloy AF350 (AlMg1/AlMg5.7/AlMg1) offers the required strength level and a significantly improved formability and thus enables the realization of the highly demanding one piece inner panel in aluminium.



Material concept for an aluminium sheet shell doors of the BMW 5 and 7 series models

(Source: BMW)

With this aluminium alloy and design concept, the weight reduction compared to the former steel doors reached 44 %.

Aluminium doors of the BMW 5xx models

(Photo: Novelis)

A modern example for an all-aluminium door is the door of the Mercedes-Benz CLS. The door of the CLS coupe is designed without a window frame. It includes an inner door sheet panel reinforced with aluminium extrusions.

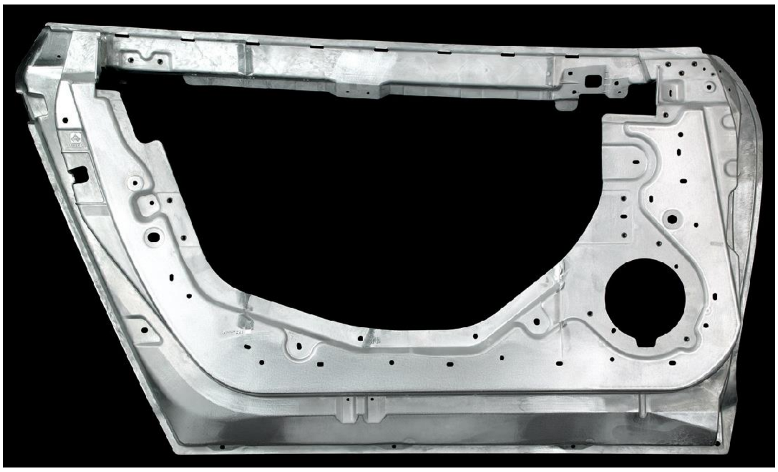
Aluminium door of the Mercedes-Benz CLS coupe

(Photo: Daimler)

b) Aluminium doors with a cast inner structural module

The vacuum high pressure die casting (HPDC) technology allows the cost-efficient production of large thin-walled castings with excellent mechanical properties. The complex, three-dimensional shape of the inner door structure with its many attachment points is an ideal candidate to be produced by high pressure die casting. The structural inner door module can be produced as a single part, saving both tool and assembly cost. On the other hand, the lifetime of die casting tools is limited, i.e. the HPDC technology is particularly suited for low to medium production volumes.

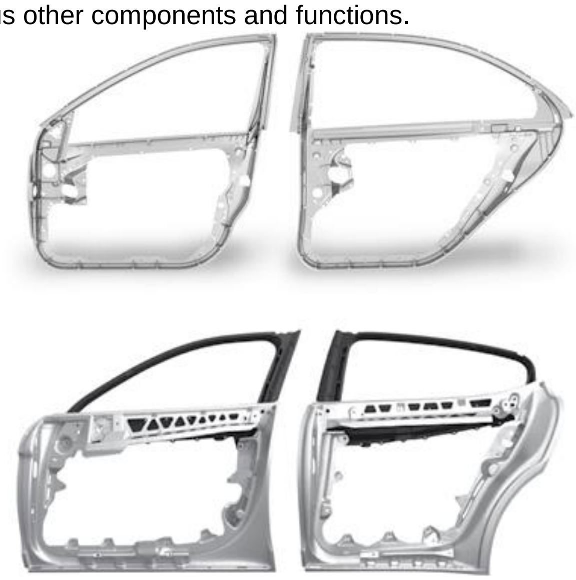
An example is the inner door structure of Nissan's GT-R sports sedan, the company's flagship, high-performance car, a part which is among the largest aluminium castings used in the automotive industry.



Cast aluminium inner door panel of the Nissan GT-R sports sedan

(Photo: Alcoa)

Both aluminium and magnesium HPDC parts are used in practice for the production of lightweight doors. The outer door panel is made from an AlMgSi sheet alloy (mainly EN AW-6016) since the surface quality of high pressure die castings is generally not suitable for outer body applications. The single-part aluminium component improves the stability of the door and supports numerous other components and functions.



Aluminium doors with a high pressure die cast aluminium structural inner module: Mercedes-Benz S class (left) and Porsche Panamera (right)

(Photos: Georg Fischer Automotive)

The inner door frames are produced using the alloy EN-AC-AlMg5Si2Mn optimized for high quality HPDC applications without subsequent heat treatment. The Mercedes-Benz S class inner door with a weight of 8.7 kg is produced in six variants by Georg Fischer Automotive. Inner door modules must meet highest quality requirements. Most important is a close control of the geometrical tolerances, minimum distortion of the as-cast part, high strength and adequate ductility. A unique feature is the upper part of the door frame, which consists of an extruded aluminium profile and is welded to the cast part. Studies on the welding suitability of pressure die casting reveal that metal inert-gas welding is most suitable.

The aluminium inner door module for the Porsche Panamera is produced similarly. However, in this case, the magnesium alloy AM50 (MgAl5Mn) is used for the window frames in order to further reduce weight and place the vehicle's centre of gravity as low as possible. The precision-cast window frame components weigh 1.7 kg for the front doors, and 1.6 kg for the rear doors. The W-profile of the 1.8 - 4.0 mm thick-walled window frame casting must meet a dual challenge: avoiding porosity and cracking in the thick-walled portion; and achieving complex geometry. The inside portion of the frames are visible and this is where the frames are joined to the aluminium casting (weight 3.9 kg) by Delta-Spot electric resistance welding. . A three-layer protective coating is applied to prevent corrosion of the magnesium part.

Even further lightweighting of the door is possible when a magnesium HPDC part is used for the inner door structure. The aluminium/magnesium hybrid door design, however, has also some disadvantages; the applicable assembly techniques must be carefully evaluated and the magnesium part must be extensively protected against corrosion. This design concept is therefore preferably used for low volume production models.

Front door of the Mercedes-Benz SL (C215) consisting of an aluminium outer panel (EN AW-6016) and a die-cast magnesium (MgAl5Mn) inner structure

(Photo: Novelis)

Other magnesium inner door modules which are used in combination with aluminium outer panels are shown below. The applied magnesium alloy is AM50 (EN MC MgAl5Mn), their weight is 4.3 kg (Mercedes-Benz SL Roadster) and 5.5 kg (Aston Martin DB9 and Vanquish).

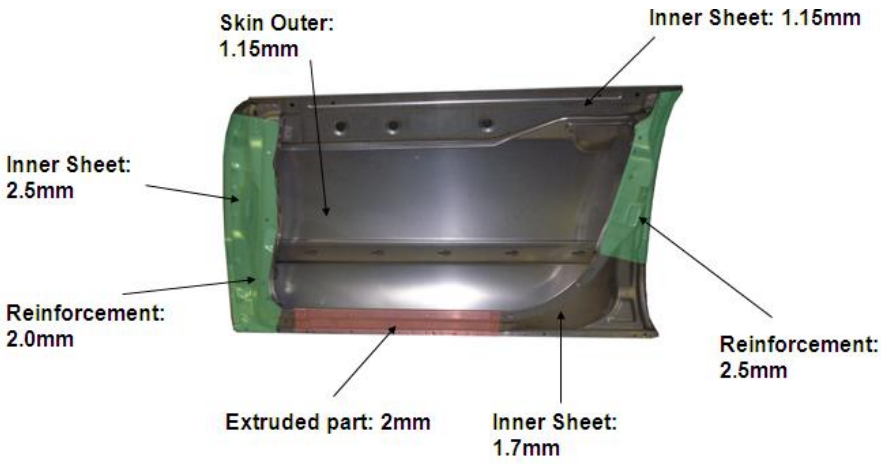
Cast magnesium inner door modules to be combined with aluminium outer door panels: Mercedes-Benz SL Roadster 230 (left) and Aston Martin DB9 and Vanquish (right)

(Photos: Georg Fischer Automotive)

c) Aluminium doors with an assembled inner door structure

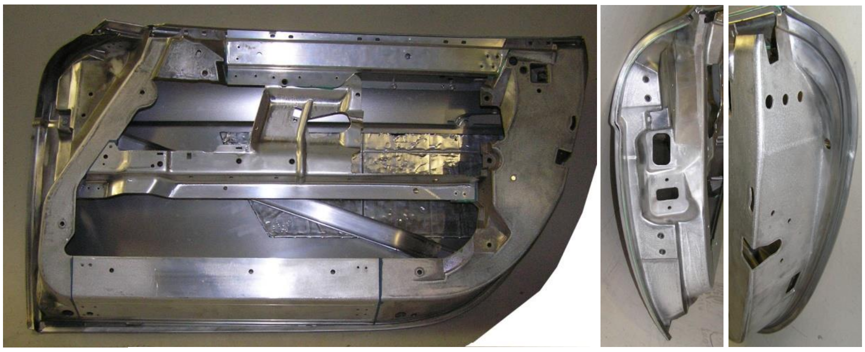
Aluminium doors with an assembled inner door structure are another alternative for low to medium production. The inner door module may consist of stamped aluminium sheet panels reinforced with aluminium extrusions, a design which was used in the first all-aluminium Audi A8. Other variants may also include aluminium high pressure die castings combined with extrusions.
When the inner door structure is assembled from different components, it is most important to look for a proper compromise assembly cost and tooling cost. This means that the number of

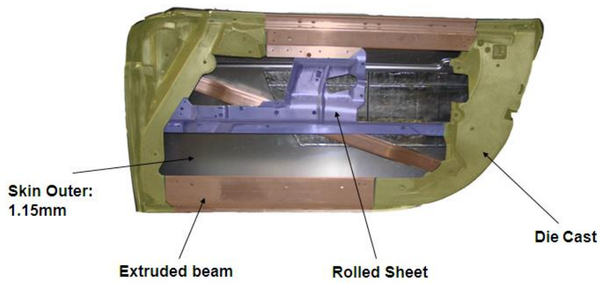
parts should be kept to a minimum and part manufacturing techniques requiring relatively high tooling cost should be avoided. In particular, a reinforcement of the inner door panel with a properly designed aluminium extrusions is therefore a cost-effective method. The different aluminium components are usually joined by welding or self-piercing riveting.



Door of the first all-aluminium Audi A8 (D2)

(Photo: Novelis)





Front door of the BMW Z8, with an aluminium outer body panel (EN AW-6016) and an assembled aluminium inner structure including two high pressure die-cast parts

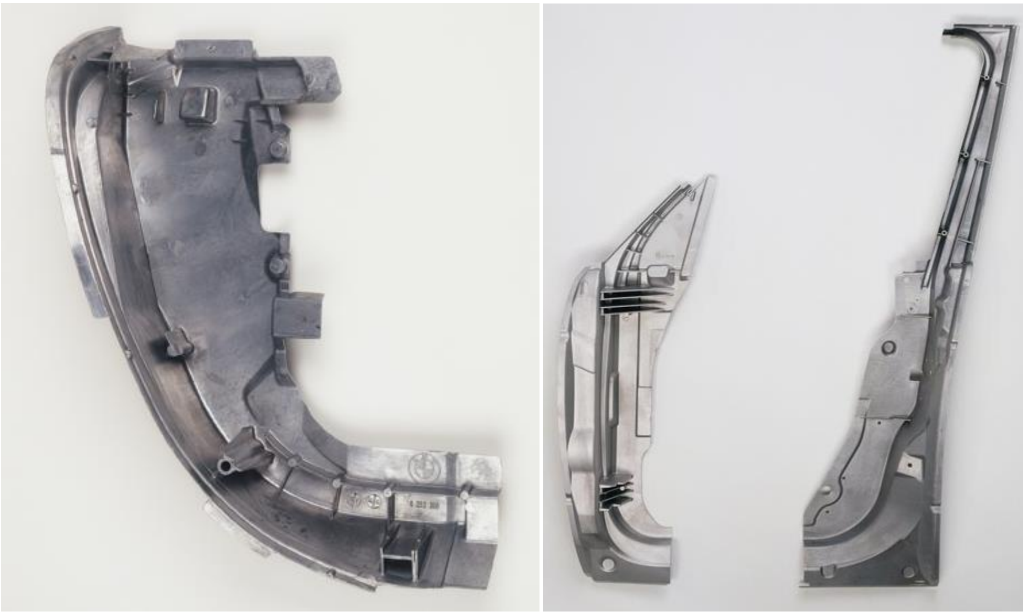
(Photo: Novelis)

Also the four VW Phaeton's doors comprise a frame construction made of aluminium castings, sheets and extruded sections, which give the vehicle its unrivalled side-impact protection. In order to largely eliminate the drawbacks of pure laser welding at important, safety-critical locations, VW opted to use the Fronius LaserHybrid welding technology. In this process, laser welding and arc welding are combined in such a way that the advantages of both processes complement each other and additional synergies result as well. All in all, there are 3570 mm of LaserHybrid-welded seams on a Phaeton door.

Aluminium door of the VW Phaeton

(Photo: Fronius)

When aluminium castings are used for door inner parts, both the alloy and the applied casting process have to satisfy highest quality requirements. In general vacuum-assisted high pressure die casting techniques are used. The wall thicknesses of the cast parts are of the order of 2 – 4 mm.



High pressure die cast inner door part for the BMW Z8 (left) and the Range Rover (L322) (right)

(Photo: Aluminium Rheinfelden)

In case of the BMW Z8, the applied casting alloy is Silafont®-36 (AlSi9MgMn); the component is used in the as-cast state. For the Range Rover door, the high quality casting alloy Magsimal®-59 (AlMg5Si2Mn) is used.

3.3.2 Aluminium door frame modules

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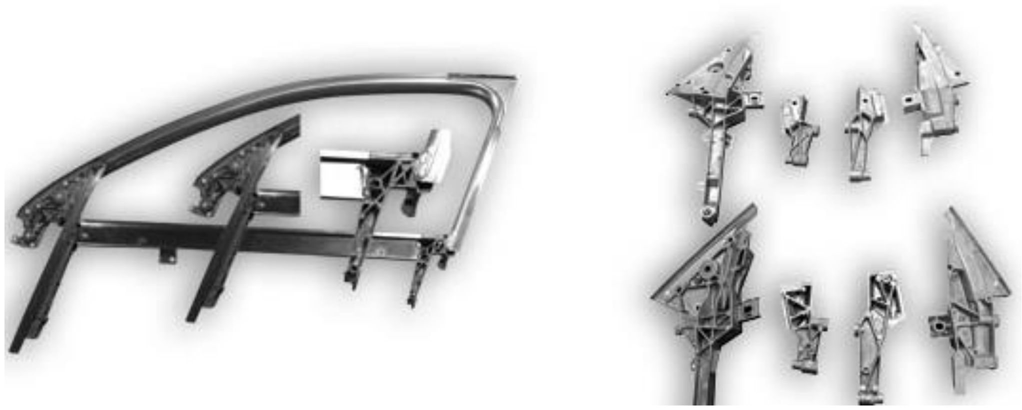
Door frame modules have been an early application of aluminium. The door frame modules were usually welded constructions integrated in a steel sheet door, generally made from extruded aluminium sections.

Audi A6 (C5) (left) and Audi A3 (8L) (right) door frame modules, welded designs made with aluminium extrusions

For the Audi A8 with its all-aluminium body, the same design concept has been used for the window frame, but it has been welded to the aluminium door inner panel.

Audi A8 (D2): Front door inner panel with extruded window frame (welded construction)

High pressure die cast aluminium nodes are also used as reinforcement in the window frame. The examples shown below are produced using the alloy Magsimal®-59 (AlMg5Si2Mn) in the as-cast state. They are welded to aluminium extrusions.



Aluminium die castings for the reinforcement of door window frames

(Photo: ae group)

Another example is the Smart door. In this case, the door includes a plastic outer panel which is attached to an aluminium frame. The aluminium frame with a weight of 3.5 kg consists of straight and stretch bent EN-AW 6060 extrusions, joined by arc welding. There is no need for a surface coating on the frame assembly (cost savings).

Smart door frame, made from aluminium extrusions

An interesting example for these types of door modules is the door module of the Audi TT. It satisfies the most stringent requirements in terms of design, comfort, safety and rational assembly. The door module in the Audi TT is the first structure-supporting door module ever used in a passenger car. In addition to the aluminium support, it also contains a window regulator with drive and electronics, the side window, the quarter light, and the window bar with seal, together with various adjusting components.

Structure-supporting door module produced in aluminium

(Photo: Küster)

An optimized lightweight door system has been introduced in the Porsche Panamera. In addition to the cast aluminium inner structure and the cast magnesium frame, the door also includes an aluminium functional carrier plate. The door structure is 25 % lighter than comparable doors in this segment.

Aluminium functional carrier plate for the Porsche Panamera

(Photo: Brose)

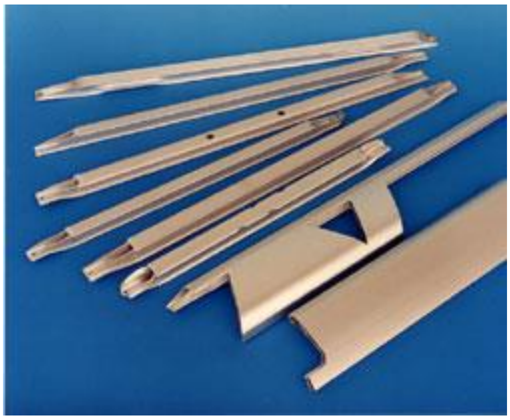
Another aluminium concept for an integrated inner panel module makes use of the superplastic forming technology. It achieves significant weight reduction and integrates the intrusion beam for superior crash management.

Aluminium integrated inner panel module produced by superplastic forming

(Photo: Magna)

3.3.3 Door side impact beams

The function of the side impact protection beam is the absorption of the crash energy in the door area and the protection of the vehicle's occupants. The deformation of the door must to be limited in order to facilitate the opening of the door after the crash and to provide enough space for the side air bag between the door and the seat. However, crashworthiness is not the only issue which has to be considered. In many cases, package compatibility is even harder to achieve. Also sufficient corrosion resistance is required because the side impact beam is within the wet zone of the door assembly. Finally the designer needs to choose a proven manufacturing process. This process has to be cost effective and guarantee the targeted production volume.



Assortment of extruded side impact beams

(Photo: Constellium)

With the increasing size and height of vehicles on the road, including SUVs and vans, side impact beams have become a more popular safety feature for cars of all sizes. The most common solutions for side impact beams are round steel tubes, press-hardened or ultra-high strength steel sections and extruded aluminium sections. Extruded aluminium beams provide the same performance with less weight than the traditional steel beams. Extruded aluminium side impact beams have been used for years for their good energy absorption characteristics and buckling performance. The properly designed cross section of the extruded aluminium profile prevents early failure through local buckling which is the failure mechanism of steel tubes in three point bending. Only recently, they are being challenged more and more by steel designs using highest strength grades and load-oriented cross section with varying wall thickness. However, the total systems approach still allows the offer of innovative aluminium solutions which are competitive on a cost per kg weight saved basis.

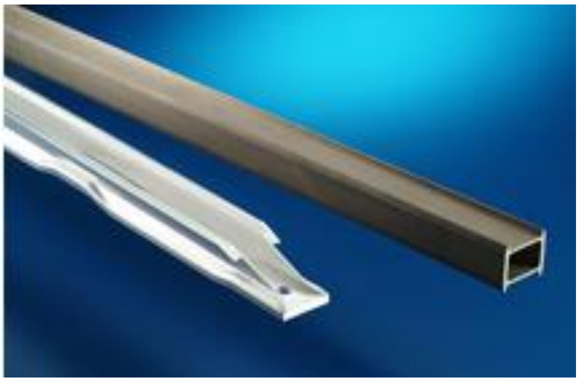
The relevant loading mode for the side impact beam is global bending. Aluminium impact beams are produced using age-hardening alloys from the AlMgSi or AlZnMg system (e.g. EN AW-6082 and EN AW-7020). The extruded sections are heat treated to the desired mechanical properties to produce the required impact load vs. displacement characteristics and a stable, predictable deformation.

Most important for this application of extruded aluminium profiles is also the design of the cross section geometry. Controlled wall thickness variation allows the realization of additional advantages, e.g. additional weight reduction or improved flank protection by the attachment of a connection to the sill member. In addition, multi-hole cross sections enable tailor-made solutions with minimum packaging requirements.

Cross sections of side impact beam optimized for minimum weight (left) and improved flank protection (right)

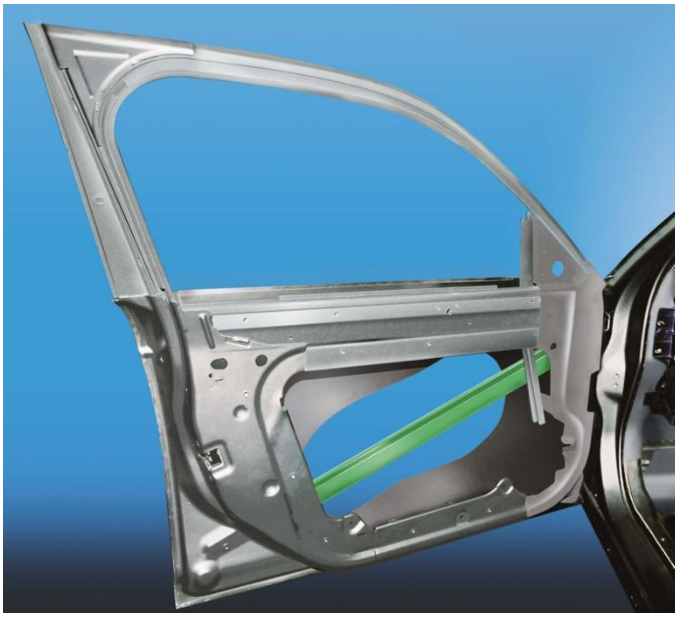
(Source: Constellium)

Aluminium may be easily shaped into a complex 3D-geometry. With this design flexibility, a number of cost and weight effective designs have been produced and have been incorporated not only into aluminium doors, but also into all-steel sheet designs. No specific surface protection is required even in a mixed material design. The aluminium side impact beam is normally mechanically joined to the steel door (bolting or riveting). In addition, a solution for easy assembly by spot welding has been developed by riveting a suitably formed steel part to the aluminium beam.



Aluminium side impact beams prepared for integration into:

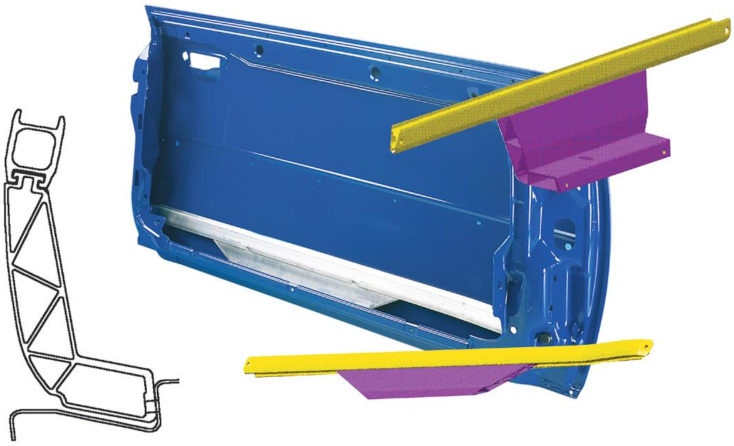
- **steel or aluminium doors by bolting or riveting (left) (Photo: Otto Fuchs)**
- **steel doors by spot welding (right) (Photo: Constellium)**



Side impact beam in the front door of the Jaguar XJ

(Photo: Constellium)

The design freedom offered by the aluminium extrusion technology allows also the realization of innovative solutions for specific side impact beams. Additional flank protection can be provided by a second extrusion which is stabilized by the door sill. The two sections are fitted into each other and fixed by a simple pinching operation.



Side impact beam with additional flank protection

(Photo: Constellium)