English Version

ATZ Extra Issue

Motor Fan illustrated

Special Edition

The more technologies are revealed, the more interesting cars become.

Discover Aluminum in the Age of electrification

Special Feature **Aluminum Technology 8**

ALUMINUM

Smart Developments

Discovering Aluminum in the Age of Electrification

The most popular lightweight material for automobiles

Automobile technology is facing a major turning point. In response to CO_2 emission regulations, expectations are rising for aluminum, which has proven itself as a lightweight material for automobiles and offers excellent workability, recyclability, and economic efficiency. Body and frame structures must be lightweight as well as highly rigid, and the performance requirements for structural materials are becoming increasingly sophisticated. Reducing the weight of the vehicle body creates a virtuous "angel spiral", in which key components such as the powertrain can also be downsized. Aluminum improves impact safety due to its energy absorption capability. Its excellent heat transfer and electrical properties also contribute to thermal management and other measures. Aluminum can be recycled over and over again, and the energy required to recycle it is a fraction of that required to produce the primary metal (new ingots). In difficult times of high energy prices worldwide, this saves energy and reduces environmental impact. Through material development, joining technology, utilization technology, and manufacturing process technology for wrought aluminum alloys, aluminum is becoming a more reliable lightweight material, even amidst the trend toward multi-materials.

Sustainable ALUMINUM for future mobility

Excellent recyclability — Environmentally sustainable new mobility — Reduction of emissions

German engineer Heinrich Dürkop presented the first aluminum-bodied sports car at the Berlin Motor Show in 1899. Two years later, Karl Benz developed a car with an aluminum engine. Aluminum unibody vehicles were already being produced by Porsche and other automakers in the 1950s, and in the 2000s, Audi and other automakers began to use aluminum space frames. Aluminum utilization technology will be further refined with the trend toward EVs.

History of Aluminum Applications in Automobiles

1899
Heinrich Durkopp
1901
Karl Benz
1904
Great Arrow


1905
Packard Model N Runabout
1915
Pierce-Arrow
Model 66-A


1924
Ettore Bugatti's brilliant Type 35


1937
Mercedes-Benz
540 K Streamliner


1953
Panhard Dyna Z

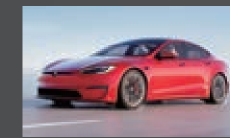

1981
Porsche 928
Audi A8 concept

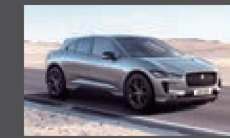

1989
Acura NSX

1993
Audi A8
1996
Lotus Elise
1999
BMW Z8 roadster
1999
Ferrari F360 Modena
2003
Lamborghini Gallardo


2003
Jaguar XJ sedan


2007
Audi A8
2009
AMG SLS
2012
Range Rover


2012
Tesla Model S
2018
Alpine A110


2019
Jaguar I-PACE

History of Aluminum Alloy Development
(Source: UACJ Corporation)


1906
Discovery of the "age hardening" phenomenon (Germany)

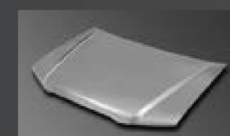

1909
Commercialization of duralumin (Germany)

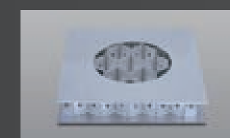

1923
Establishment of duralumin manufacturing technology

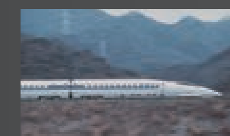

1928
Development of super duralumin (U.S.A.)
1934
Super duralumin adopted for aircraft


1936
Dr. Igarashi succeeded in developing extra super duralumin


1970
Japan's first LNG tank material
1971
Japan's first beverage can body material


1978
GZ45, Japan's first body panel material
1988
High-strength ZG62 for front forks


1991
Invention of brazed oneycomb panels


1997
Brazed honeycomb for 500 Series Shinkansen
1998
FSW applied to 700 Series Shinkansen


2012
Development of inverter coolers for hybrid vehicles, etc.
2015
Development of bumper system

Physical Properties of Aluminum

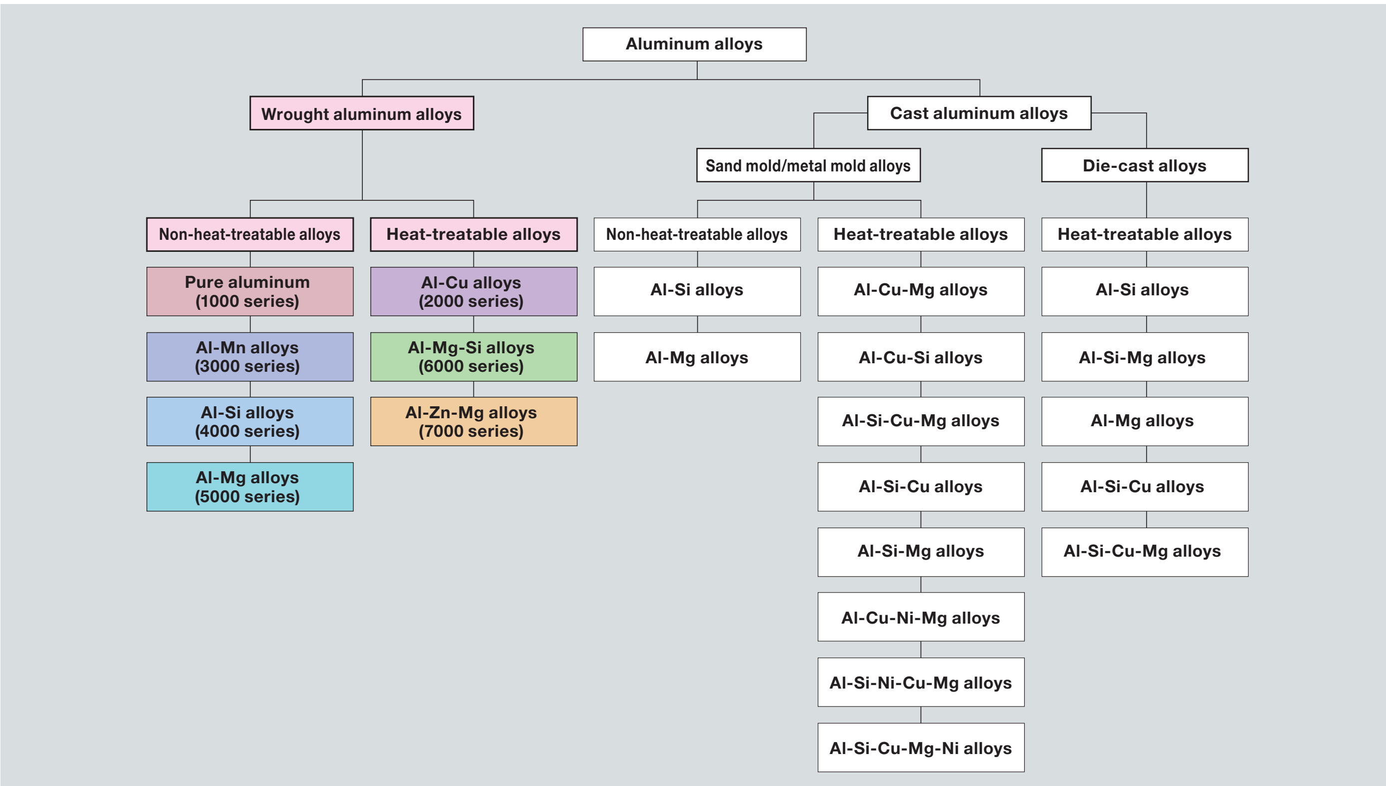
Density	2.7g/cm³
Modulus of longitudinal elasticity	70kN/mm²
Transverse modulus of elasticity	26kN/mm²
Poisson's ratio	0.33
Coefficient of linear expansion	2.4×10-5(/°C)
Thermal conductivity	225W/m・°C(25°C)
Conductivity	59(Soft) 57(Hardness)

Photo: Packard, Bugatti, Mercedes-Benz, Panhard, Porsche, Honda, Jaguar, Audi, Tesla

Discovering Aluminum in the Age of Electrification 1

It' s said that the use of one kilogram of aluminum can reduce the body weight by one kilogram. Its energy-saving effect improves fuel efficiency and contributes to the reduction of CO_2 emissions. Aluminum alloys support sustainable automobile manufacturing with a wide range of variations that satisfy the properties required of structural materials for automobiles.

Wrought aluminum alloys are classified into a series of alloy systems, indicated by thousand units. They range from the pure aluminum of the 1000 Series to the Al-Zn-Mg alloys of the 7000 Series, according to the type of additive elements, Expanded materials are processed into various shapes, such as sheets and foils by rolling, and shapes, tubes, and rods by extrusion. Forgings are also included in this category. Aluminum alloys for casting are classified into two systems: those for sand and mold castings and those for die casting. In the system chart shown here, it appears that there are more types of alloys for casting than for drawing, but in fact there are a great many types for drawing.



Guidelines of aluminum alloy choices for automobile components

The 1000 Series is used for heat exchanger parts due to its excellent corrosion resistance and workability; the 3000 Series is used for piping; and the 4000 Series is used for forged parts due to its excellent heat resistance and wear resistance. The 5000 series is used for various press-formed parts; the 2000 Series is used for parts requiring strength; and the 6000 Series and 7000 Series extruded shapes are used for chassis structural parts and bumper beams.

Alloy evaluation

✔: Very good
✓: Good

A: Good
B: Standard
C: Inferior

				Features required for aluminum alloy						Major alloy for choice
				Strength	Formability	Corrosion resistance	Arc weldability	Spot weldability	Extrusion performance & Forgeability	
Classification and Uses		Sheets	Panels (outer panels)	✔	✔	✔		✓		5000/6000
			Structural parts	✔	✔	✔	✔	✓		5000/6000
			Non-structural parts		✔	✔		✓		1000/3000/5000/6000
		Extruded shapes	Structural parts	✔	✓	✔	✔	✓	✔	6000/7000
		Forged products	Structural parts	✔	✓	✔		✓	✔	6000
Alloy	Non-heat-treatable	1000 series	Pure aluminum	C	A	A	A	A	A	
		3000 series	Al-Mn	C	A	A	A	A	A	
		5000 series	Al-Mg	B	A	A	A	A	C	
	Heat-treatable	2000 series	Al-Cu	A	C	C	C	C	B	
		6000 series	Al-Mg-Si	B	B	A	B	B	A	
		7000 series	Al-Zn-Mg	A	C	C	B	C	B	

General properties & applications of aluminum alloys

1000 Series

The 1000 series is an industrial pure aluminum material with an aluminum composition of 99.00% or higher. 1100 and 1200 are typical alloys. The names 1050, 1070, and 1085 indicate that their aluminum purity is 99.50%, 99.70%, and 99.85% or higher pure aluminum respectively. The 1000 series has low material strength, but excellent corrosion resistance, workability, and surface treatment properties. 1060 and 1070 have excellent electrical and thermal conductivity, and they are used for power transmission and distribution equipment and heat-dissipating parts.
Because of the beautiful color tone unique to aluminum obtained through anodic oxidation treatment, they are also used for nameplates and reflective panels.

2000 Series

Al-Cu heat-treated alloys are represented by 2017 and 2024, known respectively as "duralumin" and "super duralumin". They feature excellent strength and good machinability comparable to steel. However, they are inferior in terms of corrosion resistance, so applications in severely corrosive environments require adequate anti-corrosion treatment.
This series has good machinability, and free-machining alloys such as 2011 are widely used for transportation equipment and machine parts. 2014 is a representative alloy for forging materials, and is used for structural materials as well as vehicle and automobile components due to its high strength and relatively good formability.

3000 Series

The Al-Mn non-heat-treatable alloys 3003 and 3004 are representatives of this series. The addition of Mn increases strength by 10-20% compared to the 1000 Series alloys, and they also have excellent deep drawability. For this reason, they are widely used in the fields of vessels, construction materials, containers, and offset printing plates.
3004 and 3104 are alloys in which about 1% Mg is added equivalent to 3003 to further increase strength. Typical applications include body materials for beverage aluminum cans. In addition, 3003 and 3004 are often used as cladding material for heat exchangers.

4000 Series

4032 and 4043 are typical non-heat-treatable Al-Si alloys. 4032 is an alloy in which the addition of Si suppresses thermal expansion and improves wear resistance, while the addition of Cu, Ni, and Mg improves heat resistance. It's used in pistons, cylinders, valves, and bearings.
4043 is a typical welding material containing 5% Si. It's suitable for welding Al-Mg-Si alloys and aluminum castings because of its low melting temperature and high resistance to high-temperature cracking of the metal to be welded. It's used as welding wire, welding rods, and brazing sheets.

5000 Series

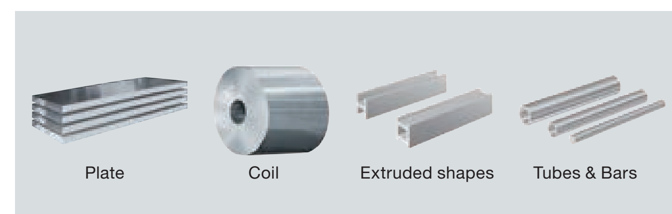
Al-Mg non heat-treatable alloys with Mg content of 0.4% to 5% have excellent corrosion resistance and surface treatability, and therefore have a wide range of uses.
The 5110 alloy with low Mg content is used for decorative materials and vessels, and 5005 for vehicle interiors. The medium-strength 5052 alloy with Mg content of about 2.5% is a general-purpose 5000 Series alloy. And the 5083 alloy with high Mg content is considered a welded structural alloy, featuring the highest strength among non-heat-treatable alloys as well as excellent weldability, seawater resistance, and low temperature properties. It's used for ship components, vehicle components, low-temperature tanks, pressure vessels, etc.

6000 Series

Al-Mg-Si heat-treatable alloys have excellent strength, corrosion resistance, and surface treatment properties. 6061 and 6063 are representative structural materials. 6061 is a sheet material with a trace amount of Cu added to increase strength, and 6063 is an extruded form material. In particular, 6063 is a representative alloy for aluminum extruded shapes and is used for building sashes, automobile components, and electrical products. Alloys of this series are also increasingly being used for automobile body panels. 6000 series materials have bake-hardening properties that increase strength during the paint baking process, while also improving dent resistance.

7000 Series

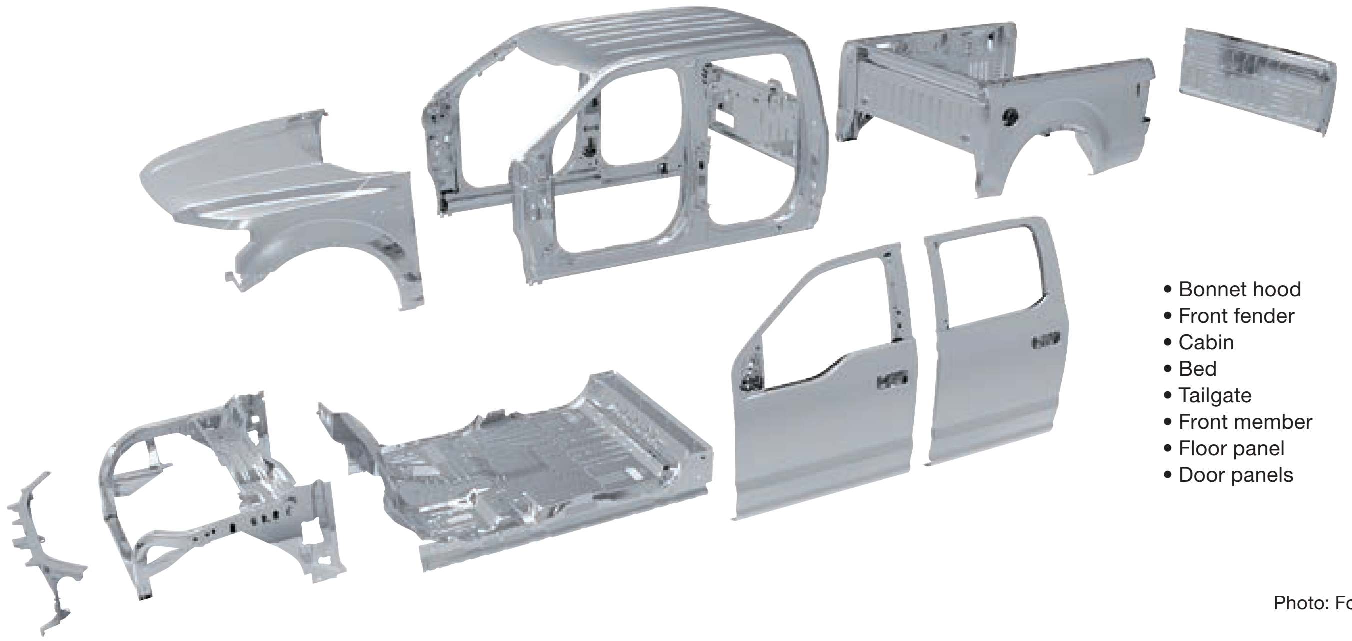
The 7000 Series can be classified into the Al-Zn-Mg-Cu alloys, which have the highest strength among aluminum alloys, and the Al-Zn-Mg alloys for welded structures that do not contain Cu, and are used for parts requiring high strength and weight reduction. 7075 is a typical heat-treated Al-Zn-Mg-Cu alloy called super duralumin, and is used as a structural material with lightweight strength.
7204 is a typical heat-treated Al-Zn-Mg alloy for welded structures. It's used in railroad cars and land structures because of its high strength and excellent joint efficiency, where the heat-affected zone after welding recovers to a strength close to that of the base metal through natural aging.



Discovering Aluminum in the Age of Electrification 2

eMobility Technology
Sustainable Aluminum for Future Mobility

Aluminum alloys are used in a variety of applications. Aluminum sheet is used for body panels. Aluminum extruded shapes are used for various frame structural members that require strength and rigidity, taking advantage of their complex cross-sectional shapes and long uniform length. Forged aluminum alloys are ideal for critical safety components because of their high strength and ability to withstand repeated stress. In addition, aluminum alloys are expected to be used as structural members for next-generation vehicles.



- Bonnet hood
- Front fender
- Cabin
- Bed
- Tailgate
- Front member
- Floor panel
- Door panels

Photo: Ford

6000 Series aluminum alloy sheets for body panels

The 6000 Series aluminum alloys are ternary alloys made by adding Mg and Si to aluminum and heat-treating. They have medium strength and good workability. 6000 series sheets have low strength and good formability when formed, and their strength increases after paint baking. There is a wide range of performance requirements for automobile body materials. In addition to formability, corrosion resistance, bake hardenability, and dent resistance, another important property is their vivid paintability.
UACJ has launched aluminum alloys for 6000 series body panels that can be bent more severely than flat hemming.

Mechanical properties

Types and mechanical properties (Sheet thickness: 1mm)

Alloy designation	AA*1	Tensile strength (N/mm^2)	Proof stress (N/mm^2)	Elongation (%)	Proof stress (after baking)*2 (N/mm^2)	Remarks
SG712-T4	(6116)	240	130	28	205	High BH type
SG712-T4 High formability type	(6116)	245	135	30	170	High formability type
TM30-T4	(6005)	210	110	27	190	High hemmability type

*1 AA: The Aluminum Association (U.S.A.); numbers show the equivalent alloys.
*2 Baking conditions: After applying 2% pre-distortion, test value after 20 minutes at 170°C.

Formability

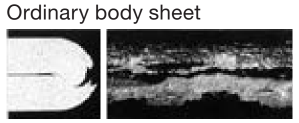
(Sheet thickness: 1mm)

Alloy designation	Formability	Hemmability	Corrosion resistance	BH effect	Ridging resistance
SG712-T4	A	A	A	A	A
SG712-T4 High formability type	A+	A	A	B	A
TM30-T4	A	A+	A	A	A

*standard B > A > A+

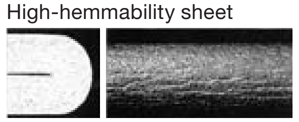
Hemmability

Ordinary body sheet



Breaks in adhesion bending, but can manage with flat hemming.

High-hemmability sheet



Can be subjected to sharp bending, which is more problematic than flat hemming.

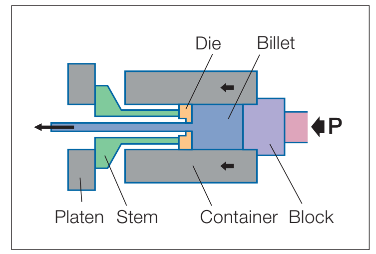
Bake hardenability

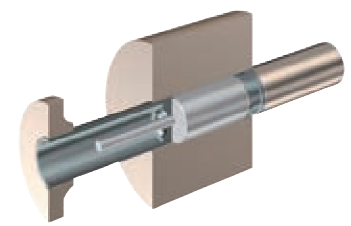
Alloy designation	2% pre-distortion + 20min at 170°C		
	Tensile strength (N/mm^2)	Proof stress (N/mm^2)	Elongation (%)
SG712-T4	285	205	23
SG712-T4 High formability type	275	170	23
TM30-T4	270	190	22

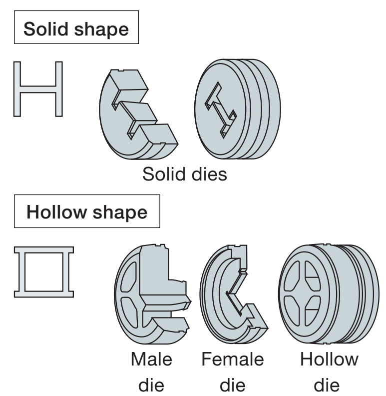
Source: UACJ Corporation

Aluminum alloy extruded products for automobile applications

Aluminum extrusion is a process in which cylindrical materials called billets heated to 400°C to 500°C are pressed against a die under strong pressure by an extruder. It can produce hollow-sectioned products called hollow shapes and long products with complex cross-sections with high precision. Aluminum extruded shapes are widely used for automobile components. 6000 Series and 7000 Series alloys are widely used for automobile structural components.
6005A and 6005C have a strength between 6061 and 6063 and feature excellent extrudability, hardenability, corrosion resistance, and weldability. 6061and 6082 are suitable for structural components, while 6110 is the highest strength alloy that can be hollow extruded. ZK170 is mass produced for high-strength bumper beams.







Alloy series	Alloy designation			Mechanical properties			Properties
	AA*	UACJ	Temper	Tensile strength (N/mm^2)	Proof stress (N/mm^2)	Elongation (%)	Hollow extrusions
6000 series	6063	6063	T5	215	190	13	✔
	6005A	6005A	T5	290	260	12	✔
	6005C	6005C	T5	270	240	11	✔
	6061	6061	T6	300	265	17	✔
	6061	661S/CM61	T6	335	300	18	✔
	6082	6082	T6	345	310	14	✔
	6110	6110	T6	380	350	12	✔
7000 series	7003	7003	T5	320	270	19	✔
	7204	7204	T5	390	340	16	✔
	7204	K70Y	T5	415	360	16	✔
	-	ZK55	T6	435	390	14	✔
	7046	ZK170	T6	450	420	14	✔
	-	ZK80	T6	530	500	13	✔
	7075	7075	T6	560	500	13	
	7050	7050/ZG62	T6	620	570	13	
	-	ZC88	T6	650	600	13	
5000 series	5052	5052	H112	190	80	28	
	5154	A254S/5154	O	240	115	27	
	5083	5083	H112	310	170	20	

* AA: The Aluminum Association (U.S.A.)
Stress-corrosion cracking performance and weldability differ depending on usage environment.

Forged aluminum alloys for automobile applications

Aluminum forging produces highly reliable aluminum parts that can withstand impact and repeated stress. It's classified into cold forging, performed at room temperature, and hot forging, in which the material is heated to about 450°C. As for the two types of forging, in die forging a die is used to forge a shape close to the final form, whereas no die is used in free forging.

Property	AA*	UACJ	Temper	Tensile strength (N/mm^2)	Proof stress (N/mm^2)	Elongation (%)	Forgeability	Machinability	Corrosion resistance
High-strength	6061	6061	T6	315	275	19	A+	A	A+
	6082	6082	T6	325	300	18	A+	A	A+
	-	SG210	T6	400	360	18	A+	A	A+
	2014	2014	T6	480	410	13	A+	A+	B
Abrasion resistance	4032	4032	T6	380	315	9	A	A	A
	-	SC100	T6	440	390	8	A	A	A
	-	TF12B	T6	430	380	8	A	A	A
High-temperature strength	-	2618	T6	440	370	10	A+	A+	B
	-	CG29	T6	520	400	14	A+	A+	B

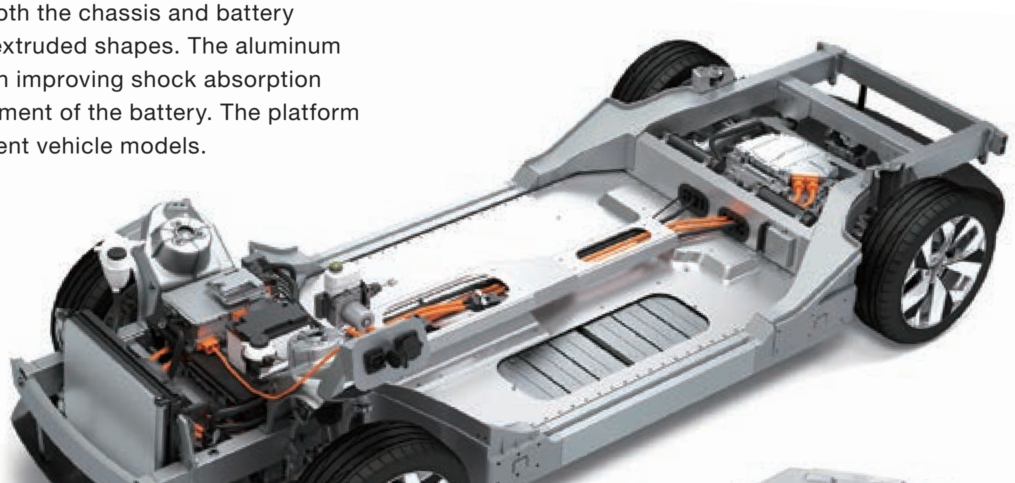
* AA: The Aluminum Association (U.S.A.)
A+: Excellent A: Good B: Not good

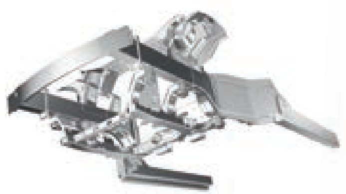
Aluminum Alloy Platform and Body Structure

Automakers are now developing common platforms for EVs, and many of them are using aluminum alloy structural materials. Daimler has developed MEA (Modular Electric Architecture), an aluminum alloy EV platform. Volkswagen has developed a scalable MEB (Modular Electric drive matrix). General Motors has developed the Ultium, a global EV platform with next-generation batteries at its core. And the PSA Group has developed CMP (Common Modular Platform) and eCMP for EVs.

BENTELER Rolling Chassis

The BENTELER Electric Drive System 2.0 (BEDS) platform is a lightweight and rigid platform with both the chassis and battery housing module made of aluminum extruded shapes. The aluminum components play an important role in improving shock absorption performance and in thermal management of the battery. The platform is suitable for B-segment to E-segment vehicle models.





Crushable zone system

Battery housing

Chevrolet Corvette C8

Aluminum extruded frame connected from the front rail to the center tunnel member.

The Chevrolet Corvette C8 has an all-aluminum alloy space frame structure, with high-strength aluminum extruded shapes used throughout for high rigidity. The C8 has a larger center tunnel and a new structure that emphasizes frame strength. The C8 platform material ratio is 40% extruded shapes, 39% sheets, 18% castings, and 3% others. The C8 E-Ray is a hybrid model with an aluminum alloy center tunnel holding the battery housing.

Shock towers are supported by aluminum extruded cross members and braces.

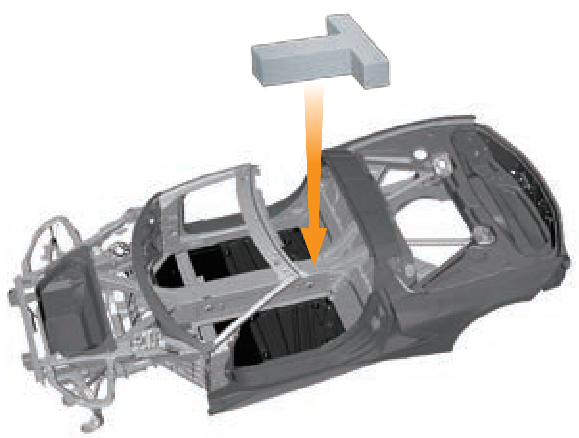
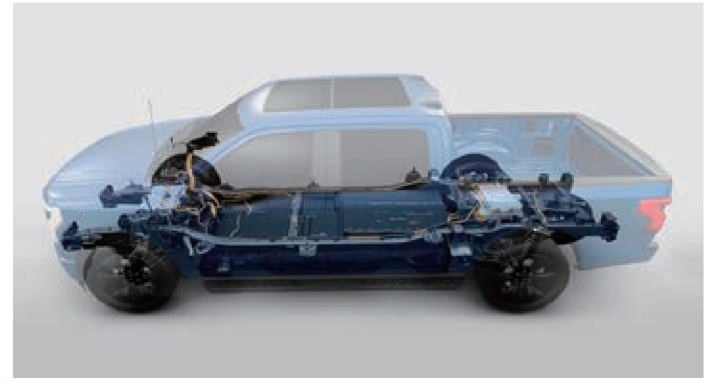


Photo: BENTELER, GM, Ford, Toyota

Ford F-150 Lightning

The weight reduction effect of the Ford F-150's aluminum upper body is as much as 320 kg. The weight reduction effect of electrification of the large body is tremendous as it affects the cruising range and payload capacity. The powerful F-150 Lightning model has a maximum output of 420 kW (563 HP). The performance has an EPA-rated range of 320 miles (515 km).



While the 2023 BEV F-150 Lightning uses a modified chassis from a gasoline-powered platform, the 2025 model will use the next-generation TE1 platform. In addition to the F-150, a small EV pickup truck like the Ford Ranger is expected to appear. Aluminum is also expected to be used further in next-generation pickup trucks.

Small Overlap Crash Test

The small overlap crash test is a frontal crash test conducted by IIHS (Insurance Institute for Highway Safety). The vehicle is subjected to a frontal collision with a barrier at a speed of 40 mph with an overlap rate of 25%, which is shallower than a conventional offset collision. Because the barrier impacts outside of the front side frames, the energy absorption mechanism of the collision is different from that of a conventional collision, and the strength required for the cabin is higher.

Lexus LS 500

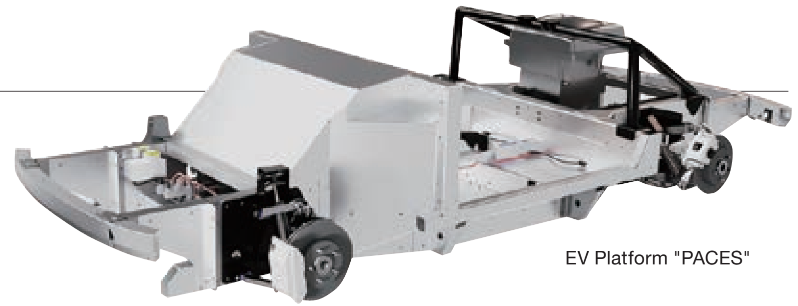
Both the inner and outer panels of the Lexus LS doors are made of 6000 Series aluminum alloy, which is approximately 25% lighter than steel doors. 5000 Series alloys with high formability are generally used for inner panels, and 6000 Series alloys with high dent resistance are used for outer panels. For the Lexus LS, the inner panels are integrally molded, which is particularly difficult. Toyota's production technology is responsible for this achievement, and aluminum manufacturer UACJ provided support.

Aluminum Alloy Automobile Components

Aluminum structural materials are utilized in the new body structure caused by electrification. The cruising range depends on the battery capacity installed, and the vehicle weight increases when a large-capacity battery is installed. The battery housing of the Audi e-tron is made of 47% aluminum extruded shapes, 36% aluminum sheets, and 17% aluminum castings. Another important factor is the structure that protects the battery by absorbing and dispersing energy in the event of a vehicle collision, as well as measures to prevent the battery from generating heat.

Aluminum EV platforms

With the ongoing development of EVs, various aluminum platforms are being created. Aluminum extruded shapes, which can be manufactured in complex cross-sectional shapes, are the perfect material for chassis frame. Welding, mechanical joining, and mechanical joining with adhesives are widely used to join aluminum extruded shapes. The PACES EV platform developed by Watt Electric Vehicles in the U.K. uses an all-aluminum alloy space frame structure and is manufactured using FlexTech, the Watt proprietary bonding technology that joins aluminum extruded shapes and aluminum components in a painting process.



EV Platform "PACES"

Aluminum crash boxes

The crash box is a component that collapses into a bellows shape to absorb energy in the event of a collision. The optimal cross-sectional shape is developed through collision simulations.

MX-5 (ND) Front bumper
Aluminum: 4.2 kg

The front bumper reinforcement of the ND Roadster is Mazda's first to use a high-strength 7000 Series alloy extruded shape to reduce weight.

MX-5 (NC) Front Bumper
Steel: 5.8 kg

The NC roadster prioritized strength in full-wrap and offset collisions, and the bumpers were made of hot-stamped steel.

Aluminum bumper reinforcement

The Mazda MX-5 (ND) structural components featured a bumper made of extruded high-strength 7000 Series alloy, which was jointly developed by Mazda and UACJ. The MX-5 (ND) was designed to be lightweight while ensuring the highest level of safety.

Aluminum battery housing

EV battery housings are made of extruded aluminum shapes in many BEVs because they must be strong enough to safely protect the battery cells from impact, efficiently dissipate the generated heat, and stably hold heavy batteries. The battery housing houses the crash frame, battery cells, cooling system, and electrical circuits.

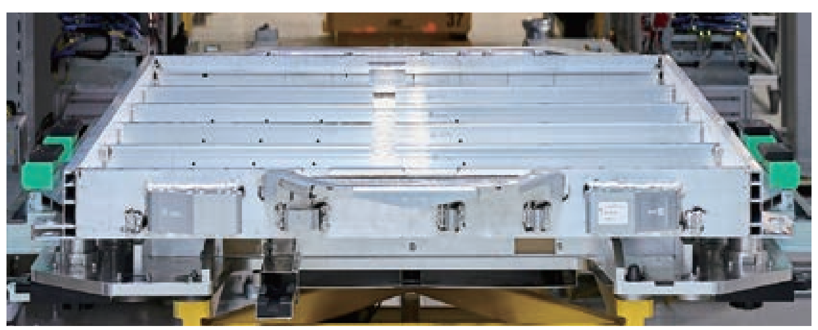
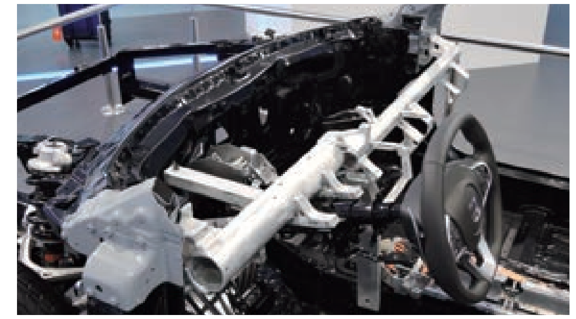
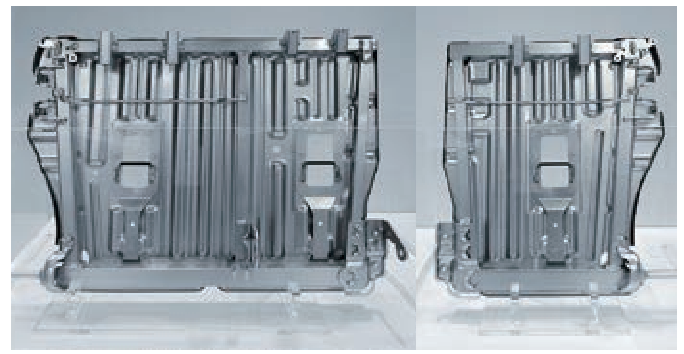


Photo: Watt Electric, Mazda, Volkswagen, MFi, ENDLESS, Continental

Aluminum alloy cross-car beam

Cross car beams connect the left and right panels under the A-pillar of the body by supporting components such as the steering wheel, instrument panel, and airbags. In recent years, the weight of the components has been increasing due to the larger displays of navigation systems. In addition to their support function, aluminum alloy beams also play an important role in the interior to reduce noise and vibration (NVH) and to obtain good user feedback.



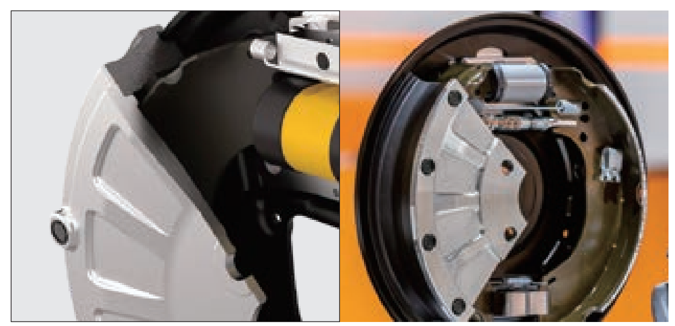


All-aluminum seat frame

This seat frame is constructed by welding 5000 Series aluminum sheets to a 7000 Series aluminum extruded shape frame, which provides the same strength and safety as steel while reducing weight by 35%. SUVs have become popular due to the variety of seating arrangements and flexible usability, and it is especially important to reduce the weight of the second-row seats.

Aluminum forged brake calipers

ENDLESS' newly developed brake calipers are forged calipers made of UACJ's aluminum alloy with high strength even at high temperatures. As vehicle bodies continue to grow in size and performance, the need for lightweight, high-rigidity forged parts is increasing. Brake calipers are exposed to high temperatures during braking, so they need characteristics that allow maximum performance in high-temperature environments. This aluminum alloy is produced through nano-level metallographic control and the heat treatment for aircraft.

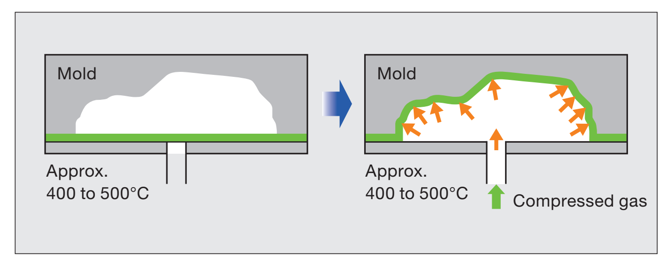


Aluminum drum brakes for EVs

Continental's aluminum alloy drum brakes for EVs are approximately 30% lighter than conventional steel drums. Regenerative braking, am electrical device unique to EVs, uses rotational resistance during power generation as a braking force during deceleration to reduce the load on the friction brake. Aluminum alloy can be used to reduce the size and weight of the brake components.

Superplastic aluminum blow forming

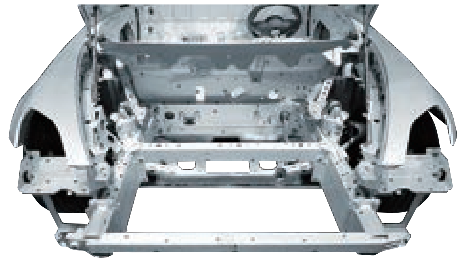
Superplastic aluminum alloys of the 5000 Series alloys (Al-Mg) can be highly elongated by several hundred percent or more at temperatures as high as 400-500℃. Using this property, free-form shapes similar to those of plastic molding can be produced by aluminum blow forming, in which heated aluminum alloy sheets are pressed into a mold by compressed gas.



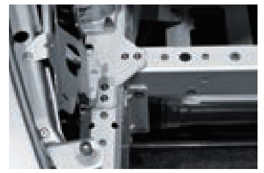
Processing and Joining

Joining technology for aluminum alloys is evolving. Laser welding, as well as FSW and FSSW, which join parts without melting them, are widely used. Mechanical joining has also evolved. The background to the increase in multi-material body structures is the spread of structural adhesives and the practical application of joining technologies for dissimilar materials such as aluminum and steel or aluminum and resin. This has also had a significant impact on lightweight body structure design.

Mechanical joining

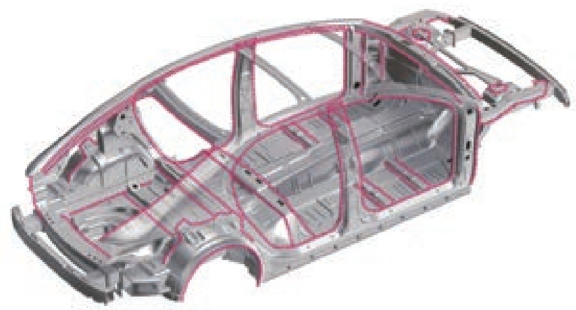


Hybrid joining, which combines mechanical joining, structural adhesives, and laser welding, are expanding for joining dissimilar materials such as aluminum, steel, and CFRP in multi-material bodies. Joining dissimilar materials present challenges such as distortion and deformation due to differences in thermal expansion coefficients between the materials and the occurrence of electrical corrosion. Self-pierce riveting (SPR) (photo: lower left). Combination of rivets and adhesives (photo: lower right).



Adhesives

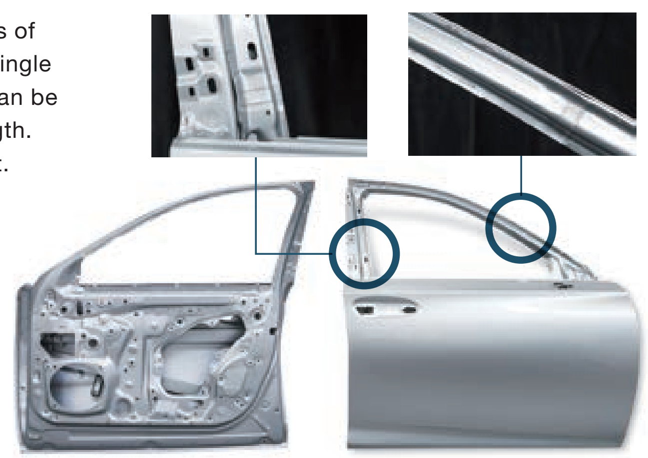
Structural adhesives are applied in a straight line between panels to be joined. The "surface contact" between panels increases joint strength and improves body rigidity, thereby enhancing handling response and ride comfort, and reducing vibration and noise. Structural adhesives are widely used in multi-material structures.



Tailored blanks

FSW/FSSW

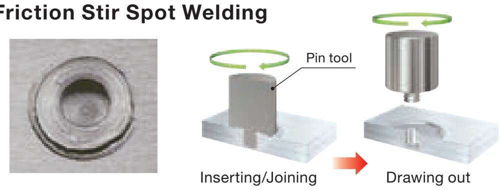
Tailored blanks are a technology for joining multiple materials of different thicknesses and materials, integrating them into a single unit, and press forming them. The required plate thickness can be optimally arranged to reduce weight while maintaining strength. The most important part of this technology is the joining part.



FSW is a joining method in which a tool with a protruding tip penetrates into the material while rotating, softening the base material by frictional heat and mixing it by plastic flow around the joint.

FSW: Friction Stir Welding
FSSW: Friction Stir Spot Welding

Friction Stir Spot Welding



UACJ's double-action FSSW leaves no holes or burrs.

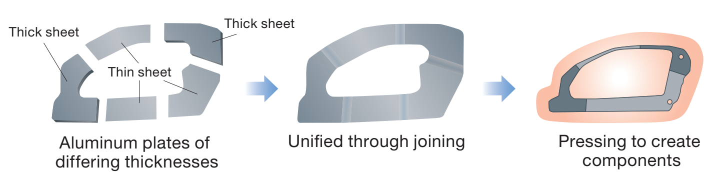


Photo: Cemedine, MFi

UACJ's Next-Generation Aluminum Technology

Aluminum alloy sheets for body panels

6000 Series aluminum alloy sheets (Al-Mg-Si) are widely used as automobile body panel materials thanks to their excellent formability, corrosion resistance, age-hardenability, and bake-hardness. UACJ has a long history of developing aluminum alloys for automobile use, and was one of the first Japanese manufacturers to develop an aluminum alloy sheet for body panels, GZ45, in 1978. In 1996 we developed a 6000 Series aluminum alloy sheet with a strength of over 200 MPa after paint baking, and in 2002 we developed a body panel material with high hemming properties. Body panels must be stably supplied worldwide, including to Japan, North America, and China. As efforts toward a recycling-oriented society have been promoted, there has been an increase in body panels using "closed-loop recycling".

Hidetoshi Uchida, Dr. Eng.

General Manager Development Department II
Research & Development Division
UACJ Corporation

Aluminum structuring of bodies

The Ford F-150 pickup truck's 320-kilogram weight reduction through the use of aluminum made an impact on reducing the body weight of large vehicles. Steel body structures remain the mainstream for recent mass-market vehicles, but large and high-performance SUVs are increasingly adopting aluminum bodies. UACJ is developing structural members using 7000 Series high-strength aluminum alloys for impact absorption components and 6000 Series high-strength aluminum alloys for frame components, as well as lightweight aluminum parts such as bumpers and crash boxes.

Akio Niikura, Ph.D.

Vice-Director of Mobility Technology Center
Automotive Parts Business Division
UACJ Corporation

Proposal-based development

Component suppliers are required to provide highly accurate technical proposals to OEMs. Although UACJ has advanced technology in rolled aluminum products, we needed to improve our development process and quality to incorporate OEM design concepts. The Mobility Technology Center (MTC) is oriented toward technology proposal-based development. Based on integrated verification, we are developing battery housings, including optimization of the assembled housing and pre-assembly components, as well as the design of the battery temperature controller flow path.

Yoichiro Kohiyama

Director of Mobility Technology Center
Automotive Parts Business Division
UACJ Corporation

Mechanical Properties of Typical Aluminum Alloys

For automobile components, the most suitable aluminum alloy is selected according to the part to be used and the required properties, such as strength, workability, corrosion resistance, and surface treatment. Aluminum alloys are made by adding elements or combining tempering to change their properties through heat treatment or machining.

Alloy series	AA*1 Equivalent alloys	UACJ (by quality)	Tensile strength (N/mm^2)	Proof stress (N/mm^2)	Elongation (%)	Sheet	Extrusion	Characteristics of materials
1000 series		A370-O	85		40	✔		Luminous aluminum alloy sheet Surface quality: HB, BF, MF
		A370-H24	120		23	✔		Luminous aluminum alloy sheet Surface quality: HB, BF, MF
2000 series	2013	113S-T6	400	375	12		✔	High-strength alloy for extrusion Hollow extrusion performance: Good
	2014	2014-T4	420	285	20		✔	High-strength alloy for extrusion
	2014	2014-T6	480	410	13		✔	High-strength alloy for extrusion
	2017	2017-T4	440	275	22		✔	High-strength alloy for extrusion
	2024	2024-T4	470	325	19		✔	High-strength alloy for extrusion
		2618-T6	440	370	10		✔	High-strength alloy for forging Forgeability & machinability: Excellent
		CG29-T6	520	400	14		✔	High-strength alloy for forging Forgeability & machinability: Excellent
3000 series		3003-O	115	40	40		✔	Alloy for tubing Hollow extrusion performance: Good
4000 series	4032	4032-T6	380	315	9		✔	Wear-resistant alloy for forging Forgeability, machinability, corrosion resistance: Good
		SC100-T6	440	390	8		✔	Wear-resistant alloy for forging Forgeability, machinability, corrosion resistance: Good
		TF12B-T6	430	380	8		✔	Wear-resistant alloy for forging Forgeability, machinability, corrosion resistance: Good
5000 series	5052	52S-O	195	90	25	✔		Alloy for body panels n value *2 =0.26, r value=0.70
	5182	GM145-O	275	135	27	✔		Alloy for body panels n value *2 =0.33, r value=0.55
	5022	GC45-O	280	130	28	✔		Alloy for body panels n value *2 =0.31, r value=0.70
	5052	52S-O	195	90	25	✔		High-strength alloy for structural purposes Shear strength: $120N/mm^2$
	5454	D54S-O	225	100	27	✔		High-strength alloy for structural purposes Stress corrosion cracking resistance: Excellent
	5154	A254S-O	240	115	27	✔		High-strength alloy for structural purposes Stress corrosion cracking resistance: Good
	5083	183S-O	290	145	24	✔		High-strength alloy for structural purposes Shear strength: $170N/mm^2$
	5110A	257S-O	110		30	✔		Luminous aluminum alloy sheet Surface quality: HB, BF, MF
	5110A	257S-H24	150		15	✔		Luminous aluminum alloy sheet Surface quality: HB, BF, MF
	5154	254S/5154-O	240	117	27		✔	High-strength alloy for extrusion
	5083	5083-O	290	145	25		✔	High-strength alloy for extrusion

*1 AA: The Aluminum Association (U.S.A.)
*2 Average value between 2% and maximum load

*Baking conditions for BH-type alloy for body panels:
Test value after applying 2% pre-distortion and 20 min at 170°C

Note: The list is made for each alloy series giving priority to the point of application for automobiles, so some material qualities may be indicated repeatedly. The figures are measures of central tendency, not guaranteed values.

Source: UACJ Corporation

Alloy series	AA*1 Equivalent alloys	UACJ (by quality)	Tensile strength (N/mm^2)	Proof stress (N/mm^2)	Elongation (%)	Sheet	Extrusion	Characteristics of materials
6000 series	6116	SG712-T4	240	130	28	✔		Alloy for body panels, High-BH type Proof stress after baking: $205N/mm^2$
	6116	SG712-T4	245	135	30	✔		Alloy for body panels, High-forming type Proof stress after baking: $170N/mm^2$
	6005	TM30-T4	210	110	27	✔		Alloy for body panels, High-BH type Proof stress after baking: $190N/mm^2$
	6111	TM66-T4	240	115	29	✔		Alloy for body panels, High-BH type Proof stress after baking: $210N/mm^2$
	6061	561S-O	120	45	34	✔		High-strength alloy for structural purposes Stress corrosion cracking resistance: Good
	6061	561S-T6	315	275	17	✔		High-strength alloy for structural purposes Shear strength: $205N/mm^2$
	6111	SG09-T6	315	260	16	✔		High-strength alloy for structural purposes Stress corrosion cracking resistance: Good
	6063	6063-T5	215	190	13		✔	General alloys for extrusion Hollow extrusion performance: Good
	6005C	6005C-T5	260	220	12		✔	High-strength alloy for extrusion Hollow extrusion performance: Good
	6061	6061-T6	315	275	19		✔	High-strength alloy for extrusion Hollow extrusion performance: Good
	6061	661S/CM61-T6	340	300	18		✔	High-strength alloy for extrusion Hollow extrusion performance: Good
	6082	6082-T6	325	300	18		✔	High strength alloys Hollow extrusion is possible
	6110	6110-T6	380	350	12		✔	High strength alloys
		SG210-T6	400	360	18			High-strength alloy for forging. Forgeability and corrosion resistance: Excellent
7000 series	7003	ZK141-T7	360	280	16	✔		High-strength alloy for structural purposes Shear strength: $190N/mm^2$
	7075	75S-T6	570	510	11	✔		High-strength alloy for structural purposes Shear strength: $330N/mm^2$
	7003	7003-T5	310	260	16		✔	High-strength alloy for extrusion Hollow extrusion performance: Good
	7204	7204-T5	360	320	14		✔	High-strength alloy for extrusion Hollow extrusion performance: Good
	7204	K70Y-T5	415	360	16		✔	High-strength alloy for extrusion Hollow extrusion performance: Good
		ZK55-T6	420	380	14		✔	High-strength alloy for extrusion Hollow extrusion performance: Good
	7046	ZK170-T6	450	420	14		✔	High-strength alloy for extrusion Hollow extrusion performance: Good
		ZK80-T6	500	470	14		✔	High-strength alloy for extrusion Hollow extrusion is possible
	7075	7075-T6	590	540	14		✔	High-strength alloy for extrusion
	7050	7050/ZG62-T6	620	570	13		✔	High-strength alloy for extrusion
		ZC80-T6	630	580	13		✔	High-strength alloy for extrusion
		ZC88-T6	650	600	13		✔	High-strength alloy for extrusion

UACJ's Next-Generation Aluminum Technologies

R&D Division (Aichi)
Mobility Technology Center

As a technology hub, UACJ's R&D Division conducts all-around research and development of various automobile materials and components in order to support the weight reduction and electrification of vehicles and contribute to the realization of a sustainable and prosperous society.

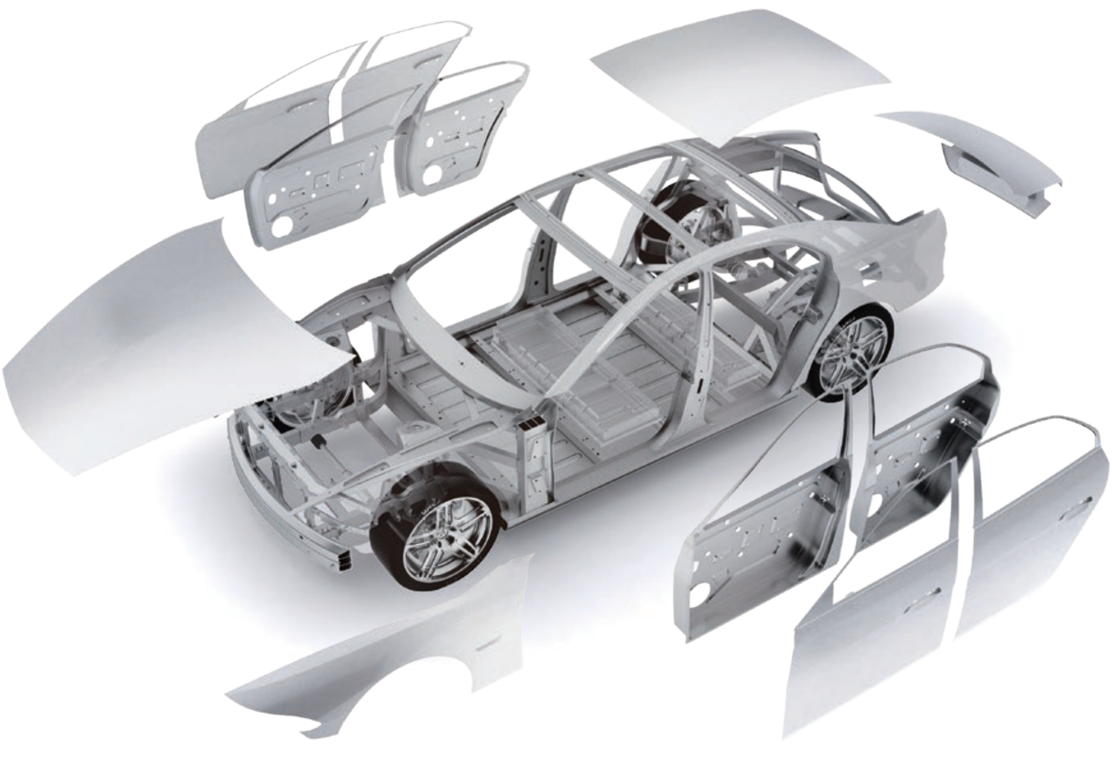
UACJ Research & Development Division

Location: Aichi Japan

Corporate Name	UACJ Corporation
Headquarters	1-7-2 Otemachi, Chiyoda-ku, Tokyo, Japan
Principal Business	Manufacture and sale of rolled products, forged products, cast products, and fabricated products of aluminum and aluminum alloys, etc.
Capital	Capital: 52,277 million yen ($405 million)

Advanced Aluminum Technology for the Automobiles of the Future

The global automotive industry is said to be in the midst of a once-in-a-century transformation. As environmental regulations are tightened, efforts to reduce CO_2 emissions are sharpening the trend toward lighter weight and electrification, and the shift to pure electric vehicles is in full swing. Automobile manufacturers are now developing next-generation mobility while looking ahead to the CASE era. UACJ is vigorously developing materials and structural applications that support weight reduction and electrification based on its accumulated expertise in a wide range of areas. Our goal is to create a new form of aluminum that no one has yet seen, but that is also the future of mobility.



Aluminum Alloy Sheets & Plates
Aluminum Alloy Extruded Shapes
Aluminum Forged Products
Aluminum Materials for Lithium-ion Batteries

UACJ Corporation

Tokyo Sankei Bldg., Otemachi 1-7-2, Chiyoda-ku, Tokyo, 100-0004 Japan
TEL : +81-3-6202-2667

Website: www.uacj-automobile.com
E-mail: automobile@uacj-groupweb.jp

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