Aluminum Material for Automobiles

The environment-friendly metal underpinning next-generation automobile development

The issue of how to reduce CO₂ emissions through the improvement of fuel efficiency has become the top priority in automobile development. One major solution is to reduce the weight of vehicle bodies... and that is precisely why aluminum is now garnering a great deal of attention. Its specific gravity is only 2.7, compared with 7.8 for steel. Aluminum, a tough high-specific strength material, has many other merits. It is highly corrosion-resistant, readily formable, and environment-friendly because it is easily recycled. What’s more, it’s a very attractive material for use in vehicles. Aluminum is increasingly being used for structural components, body panels, and a wide range of other parts, and significant advances are being made in forming and joining techniques, as well as in the development of aluminum alloys. Aluminum... Without doubt, it will become an increasingly indispensable material in automobile development.

UACJ Corporation

The largest manufacturer of rolled aluminum products in Japan, UACJ was established by the integration of Furukawa-Sky Aluminum Corp. and Sumitomo Light Metal Industries, Ltd.
Use of aluminum alloys in automobiles

**BODY & Chassis**

Automobile fuel efficiency standards around the world are becoming increasingly strict in response to global warming. In Europe, legislation is currently being prepared with the aim of setting new-vehicle CO₂ emission standards for 2020 at 95g/km. The key to achieving this is the use of materials that help reduce the weight of vehicle bodies. Thanks to improvements in the strength and workability of lightweight aluminum alloys, aluminum’s use in vehicle bodies is now moving into high gear.

**Audi A8**

The Audi A8 is the first mass-market car with an aluminum chassis. The vehicle features a unique Audi Space Frame structure with the upper body connected onto an underbody frame base.

**A pillars & roof pillars**

These connect with the roof side railings and support the upper body. They play an important role as a collision crumble zone.

**B pillars**

These support the roof and door latches, and also absorb the impact of side collisions.

**A pillars & roof pillars**

These connect with the roof side railings and support the upper body. They play an important role as a collision crumble zone.

**Front fender**

The front fender is not subjected to stress. This was one of the earliest parts to be created from aluminum alloy sheet.

**Bonnet**

Also called the firewall, this is a wall used to separate the passenger compartment from the engine room and the trunk.

**Front side members**

These are connected to the subframe. In addition to load-bearing, they are designed to absorb the impact of collisions.

**Rear side members**

These extend across from the side sills in a grid pattern. They support the passenger compartment floor and bear torsional stress.

**Trunk lid**

As with the bonnet, the use of aluminum alloys for trunk lids is also making good progress.

**Body side panels**

These are structural parts that form the structural skin of the vehicle.

**Rear side members**

These absorb the impact on the doors from side collisions.

**Aluminum alloy sheet**

This car features a mid-ship layout with a bathtub-shaped monocoque structure that is used to provide strength and rigidity to the body as a whole. This is a hybrid vehicle body featuring aluminum alloys and CFRP.

**Aluminum extruded shapes**

6000 series aluminum alloys are used for parts that require a uniform cross-sectional shape, strength, and rigidity such as bumpers, side members, side sills, etc. 5000 and 6000 series aluminum alloys are most commonly used, and 7000 series aluminum alloys when more strength is required.

**Aluminum cast products**

These commonly include cylinder blocks, transmission cases, and wheels, but moldings are also used in body components. The use of aluminum alloy die casting is appropriate when creating parts with complicated structures that require a high level of strength.

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**Aluminum alloy sheet**

The bonnet has a double-layered interior/outer structure. This is the largest exterior panel on the vehicle.

**Front side members**

These are connected to the subframe. In addition to load-bearing, they are designed to absorb the impact of collisions.

**Bonnet (inner)**

This part is used to reinforce the outer panel. With collision safety in mind, the panel structure is designed to crumple on impact.

**Bonnet (outer)**

This part is used to reinforce the outer panel. With collision safety in mind, the panel structure is designed to crumple on impact.

**Roof side railings**

**Aluminum alloy sheet**

The latest XE is an aluminum alloy monocoque vehicle based on the common Jaguar/Land Rover platform.

**Range Rover Sport**

Based on knowhow accumulated through the development of the Jaguar XJ, this is the first SUV to feature an all-aluminum body design.
Use of aluminum alloys in automobiles

**DRIVETRAIN & POWERTRAIN**

Almost all cylinder blocks are currently made from aluminum casting, and use of aluminum alloys in suspension components, which require higher strength, is also increasing.

**Suspension arms**
As critical safety components, these need to be highly reliable. The use of high-strength forged aluminum parts is increasing.

**Hub carriers**
These components connect the suspension arms with the brakes and wheels.

**Brake calipers**
As these are exposed to high temperatures while being repeatedly subjected to stress, they need high thermal stability and good abrasion resistance.

**Cylinder blocks**
Cylinder blocks made of aluminum are lighter than cast-iron blocks of the same size. Al-Si-Mg type aluminum alloys, which are suitable for die-casting, are commonly used.

**Subframes**
A subframe is a structural component that is a separate structure within a larger monocoque. It carries certain components, such as the engine drivetrain or suspension. Subframes need to have high rigidity and shock-absorbing capabilities.

**Compressor wheels for turbochargers**
These are precisely manufactured aluminum alloy impellers used to compress air. UACJ’s aluminum precision cast compressor wheels hold the world’s top share.

**Aluminum wheels**
Although both cast and forged aluminum wheels are used, forged aluminum wheels are lighter and stronger.

**Mercedes AMG GT**
The AMG GT, the flagship Mercedes sports car, features an all-aluminum body. The engine and transmission are positioned separately, with the transmission in a transaxle position connected to the engine via an aluminum torque tube.

**Lithium-ion batteries**
Lithium-ion batteries are now commonly used in note PDAs, smartphones and other mobile devices, but capacity-enhancing technologies are rapidly increasing the popularity of their use in automobiles as well.

**Use of aluminum in electric vehicles and hybrid electric vehicles**

**The Audi Q7 e-tron 3.0TDI quattro battery**
Lithium-ion batteries are now commonly used in hybrid electric vehicles, which are the most important component in electric vehicles, are made from aluminum alloys, and aluminum foil is used in the current collectors.

**The Nissan Leaf lithium-ion battery**
The battery cases and sealing components of lithium-ion batteries, which are the most important component in electric vehicles, are made from aluminum alloys, and aluminum foil is used in the current collectors.

**The Tesla Model S lithium-ion battery**
The Tesla Model S uses a bathtub-shaped frame made with aluminum alloy extruded shapes, and is equipped with a lithium-ion battery pack. The heat exchangers are also manufactured from an aluminum alloy.
Superplastic aluminum alloy sheet

Superplastic material has elongation of more than several hundred percent at high temperatures. Using the blow-forming method (using compressed gas to force heated material into a metal mold), superplastic aluminum alloy sheet permits greater design flexibility.

LIB products for EVs and HEVs

Aluminum alloy materials are also used in LIB products. They are indispensable in the production of the foil used in the positive electrode, cans, busbars, and other peripheral components.
Aluminum extruded products

Components with complex cross-sectional shapes

Aluminum extruded shapes

Using extrusion, it is possible to produce complex shapes. The process involves heating the aluminum alloy up to 400-500°C and pressing it through a die. Various shapes can be extruded, including complex shapes and hollow materials. They are normally used for automobile subframes and bumper beams.

Forged aluminum alloys

Forged materials are strong and can withstand being repeatedly subjected to stress, so they are used to produce parts such as aluminum wheels, suspension arms, and brake components, which require a high level of reliability. There are various different forging methods, including hot, cold, open die, and closed die forgings.

Aluminum Design Sheets

The aesthetically pleasing appearance of aluminum is one of its major features. The sheen of luminous aluminum alloys can be further enhanced through electrolytic and chemical polishing, and they are used for decorative parts, such as vehicle moldings. Various surface treatment technologies can be used to accentuate the aesthetic qualities of aluminum.

Aluminum Design Sheets

Aluminum alloy panels are commonly used for interior decoration, such as in the center console, door trim, and other parts of the Infiniti Q50. Their surface is very smooth, detailed and shiny.

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Aluminum extruded products

Extruded components are produced using 6060 aluminum, and there is a clear difference in the cross-sectional shape of components formed in this way. The ability to create this kind of shape is characteristic of extrusion processing. The red lines in the photo are adhesive material; a large amount of adhesive material is used in the Lotus aluminum alloy chassis.

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Evaluation and analysis technologies

UACJ works on simulations, analysis and evaluations in order to develop better aluminum alloys. Particularly useful for development is impact simulation analysis, fluid analysis and thermal analysis. CAE is used for considering the characteristics of materials and shapes to improve collision safety.

Crash boxes

The crumpling process of crash boxes during collisions is compared using experiments and CAE.
Aluminum alloy joining technologies

Welding, adhesion, and bonding of materials with different properties

As the use of aluminum alloys in vehicle bodies has become common, dramatic advances have been made in aluminum joining technologies, such as laser welding and friction stir welding. There have also been advances in mechanical joining such as riveting, screwing, and clinching, and the use of adhesive materials.

Bonding of materials with differing properties such as aluminum-iron, and aluminum-resin, is also garnering attention. Such joining technologies as these are expected to lead to a considerable increase in the use of aluminum.

FSW-FSSW

Friction stir welding (FSW) is a joining technology that involves the use of a tool with a pointed revolving tip that is pressed against the metal, which is then softened by friction-generated heat. This plasticized material is used to join pieces of metal together.

This method has many benefits, including low levels of distortion and residual stress, and less significant reduction in strength when exposed to heat.

Joining technologies

- Punch riveting
  
  Two sheets are joined by forcing a wedge-shaped fastener through them.

- Laser welding
  
  A laser light is pointed at the parts to be joined to weld them together.

- Flow drill screwing
  
  A method of screw fastening in which the fastener member can be removed.

- Self-piercing riveting
  
  The leg portion distorts and cuts into the base materials to fasten them together.

- Mechanical clinching
  
  A die is used to clinch materials together from above and below.

Tailored blanking

The first-generation Audi R8 was the first mass-market automobile to employ tailored blanking.

Tailored blanking is a production method that involves joining materials of differing thicknesses or qualities before press forming them. Since it is possible to position materials of differing strengths, thicknesses, and qualities only where they are required, the method contributes greatly to weight reduction.

Brazing

Automobile heat exchangers are produced by assembling multi-hole flat tubes and corrugated brazing sheets. To reduce weight and enhance performance, heat exchanger materials are made thinner, so corrosion proofing is vital.

Adhesion

High-adhesive strength pre-coated aluminum alloy sheet:

Aluminum alloy sheet material with a coating that is highly adhesive to resin is used to support the weather strip.

 comparison of different joining methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Thickness</th>
<th>Tensile strength</th>
<th>Formability</th>
<th>Fabricating</th>
<th>Fracturing</th>
<th>Device</th>
<th>Welding</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSW</td>
<td>2.0 - 4.0</td>
<td>2.5 - 3.5</td>
<td>Good</td>
<td>Excellent</td>
<td>Acceptable</td>
<td>Inexpensive</td>
<td>Medium</td>
<td>Inexpensive</td>
</tr>
<tr>
<td>YAG laser</td>
<td>2.0 - 4.0</td>
<td>2.5 - 4.0</td>
<td>Good</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Inexpensive</td>
<td>Medium</td>
<td>Inexpensive</td>
</tr>
<tr>
<td>Arc welding</td>
<td>0.1 - 1.2</td>
<td>0.1 - 1.2</td>
<td>Excellent</td>
<td>Good</td>
<td>Good</td>
<td>Inexpensive</td>
<td>Medium</td>
<td>Inexpensive</td>
</tr>
</tbody>
</table>

© Excellent | © Good | © Acceptable | © May require further consideration
### Aluminum usage guidelines

The table on this page explains the characteristics of the different alloys types and what automobile components they are used in.

<table>
<thead>
<tr>
<th>Alloy denomination</th>
<th>Characteristics</th>
<th>Use in automobiles</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1000 Al</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1050 A60</td>
<td>Excellent processability and surface treatability. The most corrosion-resistant of all aluminum alloys.</td>
<td>Heat insulators</td>
</tr>
<tr>
<td>1100 A30</td>
<td>General-purpose aluminum with over 99.0% purity. Surface appears slightly white after anodizing.</td>
<td>Heat insulators</td>
</tr>
<tr>
<td>1200 A0</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2000 Al-Cu</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2014 14S</td>
<td>Very strong alloy used for structural components. Because of relatively higher copper content, inferior corrosion resistance.</td>
<td>Motorcycle handles, ABS</td>
</tr>
<tr>
<td>2017 17S</td>
<td>Shock absorbers, handles, spacers, coroeds</td>
<td></td>
</tr>
<tr>
<td>2319 BI16</td>
<td>High-strength, excellent properties at high and low temperatures, superior weldability, but inferior corrosion resistance.</td>
<td>Rotors, brake components</td>
</tr>
<tr>
<td>CB156 CB256 K526</td>
<td>Higher strength at elevated temperatures than that of 2618.</td>
<td>Coroeds, pistons</td>
</tr>
<tr>
<td><strong>3000 Al-Mn</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3003 D35</td>
<td>10% stronger than 1100. Good processability and corrosion resistance.</td>
<td>Piping</td>
</tr>
<tr>
<td>3004 D45</td>
<td>Stronger than 3003. Excellent ductility, weldability, and good corrosion resistance.</td>
<td>Cowl grilles, heat insulators</td>
</tr>
<tr>
<td><strong>4000 Al-Si</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4032 35S</td>
<td>Excellent heat and abrasion resistance. Low thermal expansion coefficient.</td>
<td>Pistons</td>
</tr>
<tr>
<td><strong>5000 Al-Mg</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5052 52S</td>
<td>A medium-strength alloy. Good corrosion resistance and formability. High fatigue strength.</td>
<td>Meter display panels, AT drums, air bag inflators, covers</td>
</tr>
<tr>
<td>5454 D54S</td>
<td>20% stronger than 5052. Good corrosion resistance.</td>
<td>Wheel rims, suspension components</td>
</tr>
<tr>
<td><strong>5000 Al-Mg-Si</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5083 18S3</td>
<td>An alloy for use in welded structures. The strongest of the non-thermally treated alloys.</td>
<td>Tanks, gas cylinders</td>
</tr>
<tr>
<td>5083 28S3</td>
<td>A high formability version of 18S3. Excellent superplastic properties.</td>
<td></td>
</tr>
<tr>
<td>4035 KPS6</td>
<td>An extrusion alloy version of 18S3.</td>
<td>Lashing rails</td>
</tr>
<tr>
<td>5182 AEB1S</td>
<td>Nearly as strong as 5083. Good processability and corrosion resistance.</td>
<td>Body panels (interior)</td>
</tr>
<tr>
<td><strong>5100 Al-Zn-Mg</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5154 A514S</td>
<td>20% stronger than 5052. Good formability.</td>
<td>Wheels, underbody components, drivetrain components, suspension components</td>
</tr>
<tr>
<td>5154 A524S</td>
<td>20% stronger than 5052. Good stress corrosion cracking performance.</td>
<td></td>
</tr>
<tr>
<td>5154 A532</td>
<td>Good formability and stress corrosion cracking performance.</td>
<td></td>
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### Aluminum alloy denotations

- **AA**: Denominations used by the Aluminum Association.
- **UACJ**: Used in Japan.
- **M**: Forged parts.

**Use in automobiles**

| 5022 GC45 T019 | High-strength, high-formability body panel material. Low-coat-baking proof stress reduction. | Borrnets, roofs, doors, pillars, oil pans, floors, rear fenders, air cleaner housings |
| 5023 GC50 T025 | Body panel material with further enhanced formability. | Bonnets, roofs, trunk lids, instrument panels, seal buckets, knee protectors |
| 5110A 257S    | A high brightness alloy with the same strength as 3003. Good deep-drawability and corrosion resistance. | Moldings, trims, reflective panels, headlamp bulb shades |
| 5056 356S     | A non-heattreatable alloy for welded structures. Excellent seawater resistance. | Brake pistons, fuel delivery pipes, airbag inflators |
| 5056 356B     |                     |                    |

**Alloy denotations**

- **AA**: Denominations used by the Aluminum Association.
- **UACJ**: Used in Japan.
- **M**: Forged parts.
Aluminum alloys can be roughly divided into wrought alloys and cast alloys. These two categories can be further divided into heat-treatable alloys and non-heat-treatable alloys.

There are two different types of cast aluminum alloys: sand mold/metal mold alloys and die-cast alloys.

Wrought aluminum alloys are processed by rolling, extrusion, etc., into a wide range of different shapes, including sheets, foil, shapes, tubes, and bars. The properties of aluminum alloys change with the types and amounts of added elements.

### Rolled aluminum alloys

Rolled aluminum alloys are classified in accordance with the International Alloy Designation System (IADIS) based on an agreement to which 22 countries and 24 organizations are a party. Four-digit code numbers are used to identify alloys, and the various alloys are precisely classified according to the types and amounts of added elements and impurities they contain, and their various threshold limit values.

There are currently more than 400 different aluminum and aluminum alloys registered and administered by the system. The European standard EANW-5052 alloy and the Japan industrial Standard A5002 alloy share the same four-digit number (5052), and this means that the chemical constituents of the alloys are exactly the same. For this reason, it is reasonable to say that rolled aluminum alloy specifications are more internationalized than those of any other metallic material. Cast aluminum alloys, on the other hand, are still not subject to an international alloy registration system like the one for rolled aluminum alloys.

Reference from European Aluminium

www.european-aluminium.eu

### Cast aluminum alloys

There are two different types of cast aluminum alloys: non-heat-treatable alloys and heat-treatable alloys.

**Non-heat-treatable alloys**

- Al-Mg alloys
- Al-Si alloys
- Al-Mg-Si alloys

**Heat-treatable alloys**

- Al-Cu alloys
- Al-Zn-Cu alloys
- Al-Zn-Mg alloys

### Die-cast alloys

- Al-Si alloys
- Al-Cu alloys
- Al-Cu-Mg alloys
- Al-Si-Cu-Mg alloys
- Al-Si-Ni-Cu-Mg alloys

### Sand mold/metal mold alloys

- Pure aluminum (1000 series)
- Al-Mn alloys (3000 series)
- Al-Zn-Mg alloys (7000 series)
- Al-Mg alloys (5000 series)

The general properties of aluminum alloys

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</tr>
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<td>2000 series</td>
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<tr>
<td>4000 series</td>
<td>Moderate strength, good machinability</td>
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<tr>
<td>5000 series</td>
<td>Mid to high strength, forging and extrusion, high corrosion resistance</td>
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<tr>
<td>6000 series</td>
<td>Mid to high strength, corrosion resistance, high electrical and thermal conductivity</td>
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