

Development of Aluminum Hood for 2005 Model Year LEGEND

Noboru HAYASHI*

Katsutoshi ANDO*

Masakazu KASHIWAGI*

ABSTRACT

An aluminum hood was developed for the 2005 model year LEGEND in order to reduce cost while maintaining durability and performance requirements and help ensure pedestrian safety.

We focused on materials cost reduction for the aluminum hood skin sheet by reviewing its chemical composition and developing a 5000 series alloy produced with the continuous casting rolling method for the stiffener sheet.

Planning for general purpose processing specifications, a PVC-free acrylic acid resin system mastic sealer for steel and aluminum was applied for adhesion between the various components. Continuous multipoint self-piercing rivets were applied for the reduction of machining costs. The surface was treated with a surface conditioner that has a zinc phosphoric crystal as its main component. This allowed for the precise formation of a chemical conversion coating on the surface.

The frame structure of this developed hood was also optimized, enabling it to achieve the same performance in pedestrian safety as a conventional steel hood.

1. Introduction

The change to aluminum for external panels on vehicles to improve their dynamic performance and fuel consumption has yielded significant weight-reduction effects. Honda has therefore been applying aluminum hoods to the NSX, S2000, and INSIGHT. However, the application of aluminum sheet resulted in higher material costs than steel sheet, and lower spot weldability, so higher machining costs were an issue. Research was therefore conducted on cost reduction through lower material costs, use of general-purpose machining equipment, and so on. In addition, a hood was developed with an aluminum specification providing the pedestrian safety performance that has been included in every new model announced since the 1998 model year LIFE.

This report introduces these material technologies for aluminum sheet for hoods, adhesive bonding, surface treatment, and pedestrian safety compatibility.

2. Aluminum Hood Components

Figure 1 shows the materials and components of the aluminum hood on the 2005 model year LEGEND. A paint bake hardenable type 6000 series alloy with mechanical properties and formability equal to conventional alloys was used for the hood skin. A 5000 series alloy was used for the hood frame. A 5000 series alloy manufactured by the continuous casting rolling method was also used for the stiffener. PVC-free acrylic acid resin system mastic sealer was used to adhesively bond the hood skin and the hood frame. The hood frame and stiffeners were joined using self-piercing rivets. A surface conditioner with zinc phosphoric crystal as its main constituent was used for chemical treatment of the aluminum hood. The characteristics of the aluminum sheet that makes up the aluminum hood are shown in Table 1.

* Tochigi R&D Center

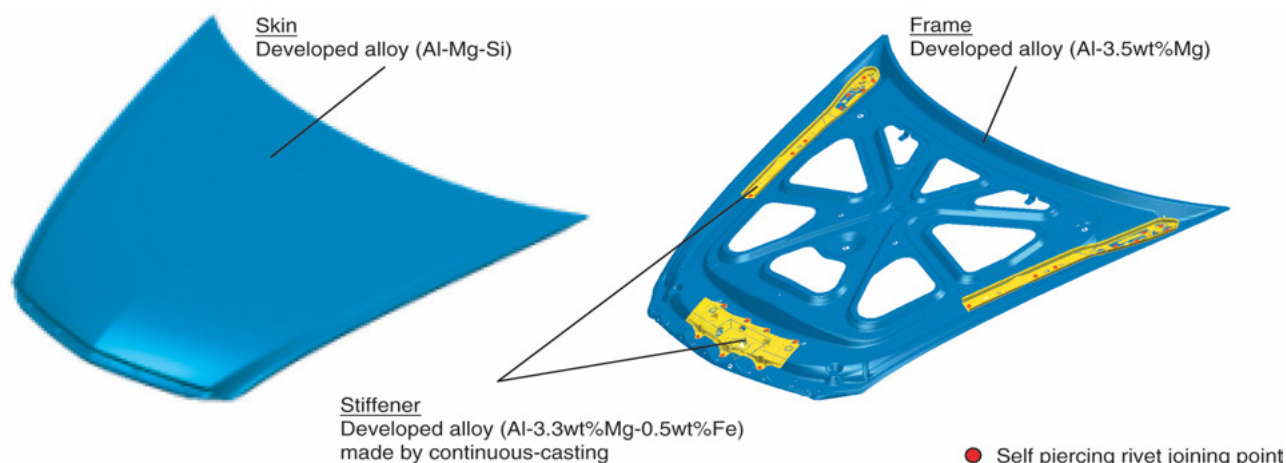


Fig. 1 Aluminum hood component

Table 1 Characteristics of aluminum hood materials

Parts	Yield stress (MPa)	Tensile stress (MPa)	Elongation (%)	Bake hard* (MPa)	Fatigue stress (MPa)	Bending
Hood skin	118	211	30	224	69	 5% Stretch 0.5R
Hood frame	123	229	28	—	118	—
Stiffener	128	239	26	—	118	—

* Bake hard : Yield stress after 180°C_×_60min & non stretch

3. Hood Skin and Hood Frame Alloys

A heat treatable 6000 series alloy that was age hardened using the heat of the paint baking process was previously used for hood skin alloys in order to improve their dent resistance. For the developed hood skin alloys, less expensive aluminum ingots containing greater amounts of Cu impurities were used in order to lower the material costs. The Cu impurities in the hood skin alloys used previously were held down to 0.01 wt% or less because corrosion resistance diminished when Cu impurity content was higher. However, the use of improved surface treatment technology for the newly developed alloy made it possible to ensure equal corrosion resistance even when the Cu impurity content was higher. When the Cu impurities reach the 0.10 wt% level, however, a fibrous microstructure remains in the final sheet product because significant recrystallization does not take place after hot rolling. When a sheet has this type of structure, ridging marks (shown in Fig. 2) appear on the surface of the sheet. These marks degrade the appearance quality of the hood. Consequently, the content was kept below a maximum of 0.07 wt%. This level increased the allowable amount of Cu impurities present, and therefore made it possible to lower material costs. A 5000 series alloy with Al-3.5 wt% Mg content for better draw forming with low yield stress was used for the hood frame.

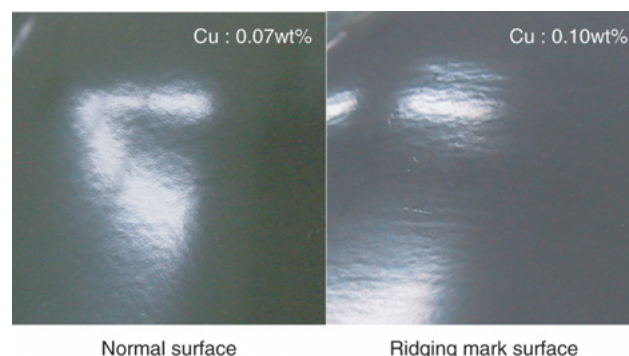


Fig. 2 Ridging mark

4. Stiffener Alloy

A 5000 series alloy manufactured by the continuous casting rolling method was used for the stiffener alloy. The continuous casting directed rolling method is unlike the conventional direct chill slab (DC) rolling method, which uses rolling to process large casting slabs into aluminum sheets, in that it continuously casts 6-mm thick aluminum plate directly from molten aluminum, and rolls it into a coil. In this method, the coil is then rolled to the final thickness to make the aluminum sheet. This method reduces the conventional 11 process steps in manufacturing aluminum sheet to 5 process steps, thereby lowering the material

Table 2 Characteristics of continuous casting alloy

Alloy type	Chemical composition			Mechanical property		
	Mg(wt%)	Fe(wt%)	Mn(wt%)	Yield stress (MPa)	Tensile stress (MPa)	Elongation (%)
A5052	2.6	0.30	0.01	86	198	25
High Fe/Mn	2.6	0.31	0.08	104	214	24
High Fe	2.3	0.39	0.00	82	209	27
High Mg	3.1	0.30	0.01	122	236	27

manufacturing cost. Because the solidification speed of the aluminum during continuous casting is also faster than with the DC method, it is possible to reduce the aluminum grain size as well as the Fe intermetallics within the aluminum matrix. This can affect the elongation of the final sheet product. Figure 3 shows the appearance of the Fe-type intermetallic compounds that crystallize in the alloy matrix of DC sheet and of continuous cast sheet alloys. The crystallized intermetallic compound is smaller in the continuous cast sheet than in the DC sheet. Figure 4 shows the crystallized grains in DC sheet and continuous cast sheet. The crystallized grains in the continuous cast sheet are significantly smaller than those in the DC sheet.

A study was made to determine whether these characteristics of the continuous casting rolling method would allow the use of less expensive ingots (containing more impurities), thus achieving a reduction in material costs. The study used continuous cast sheet based on the chemical composition of A5052 with varying amounts added of Mg, Fe, and Mn, which affect elongation. Table 2 shows the chemical composition and mechanical properties of the continuous cast sheet investigated. When larger amounts of Fe and Mn are present, more coarse Fe-Mn-type intermetallic compounds exist, as shown in Fig. 5(a), and these interfere with elongation. The result is that elongation is diminished. On the other hand, when more Fe was present but there was less Mn, then intermetallic compounds that interfere with

elongation did not appear, as shown in Fig. 5(b). Only an extremely minute Fe-type intermetallic compound appeared in these cases, and there was no decrease in elongation. When the amount of Mg was increased, elongation improved as well. These results were used to develop an Al-Mg-Fe-type alloy that can use aluminum ingots containing greater amounts of impurities with a broader range of allowable Fe content, making it possible to reduce material costs.

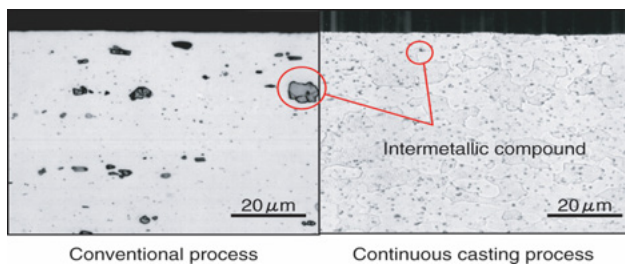
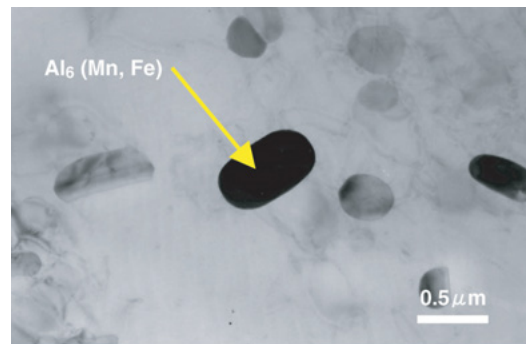
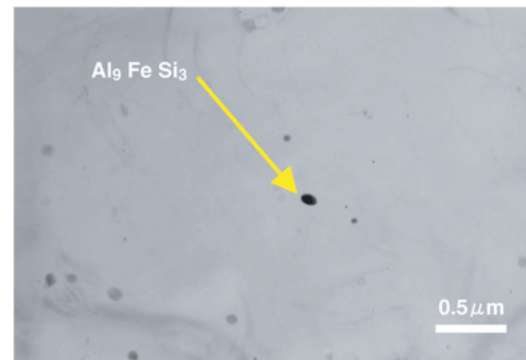


Fig. 3 Comparison of intermetallic compound



(a) Intermetallic compound in high Mn -type alloy



(b) Intermetallic compound in high Fe -type alloy

Fig. 5 Transmission electron microscopy photograph of intermetallic compound

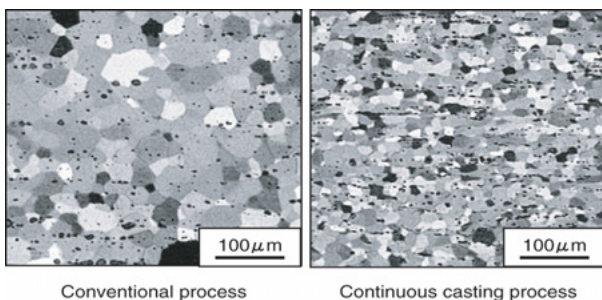


Fig. 4 Comparison of grain size

5. Adhesive Bonding and Joints

A mastic sealer with acrylic resin as the main formulation that is capable of bonding both aluminum and steel was used for adhesive bonding of the various component parts. Devising new sealer application equipment capable of shared use enabled cost reduction.

Joints were made using self-piercing rivets, raising spot weldability (the number of joint points that can continuously maintain joint quality) performance and reducing the costs of production processing. The self-piercing rivets had a chrome-free coating applied as a rust inhibitor. Figure 6 shows a cross-section of the self-piercing rivet.

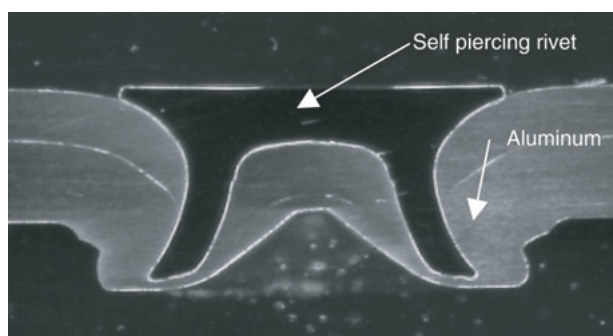


Fig. 6 Self piercing rivet cut model

6. Surface Treatment

Improvement was made to the surface conditioner that controls the formation of the chemical conversion coating during the surface treatment process. Specifically, the principal component of the surface conditioner was changed from Ti colloid to zinc phosphoric crystal in order to increase the crystallization rate of the chemical conversion coating. Figure 7 shows the change over time in the weight of the chemical conversion coating on an aluminum surface. Figure 8 shows a scanning electron microscope (SEM) photograph of the chemical conversion coating. These results indicate

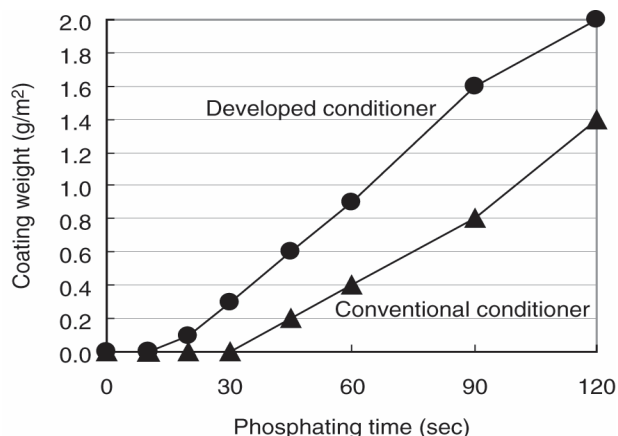


Fig. 7 Relationship between phosphating time and coating weight

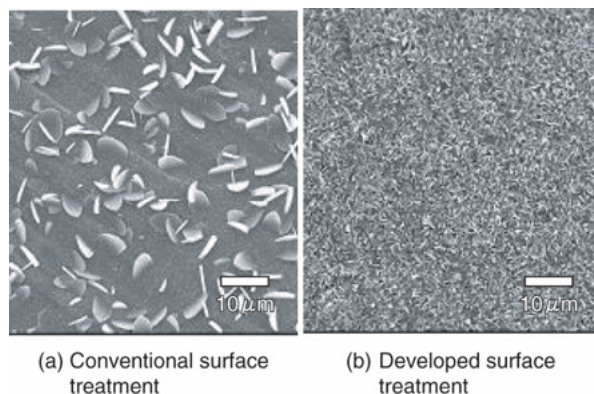


Fig. 8 Comparison of phosphoric acid zinc crystal on aluminum plate

that improvement of the surface conditioner promoted the coating deposition reaction and gave the coating greater density. Figure 9 shows the results of filiform corrosion testing following coating. When a conventional surface conditioner is used, the newly developed hood skin with its high Cu impurity content has lower filiform corrosion resistance than a conventional hood skin with its lower Cu impurity content. When the improved surface conditioner is applied, however, it is possible even for the developed hood skin material to have corrosion resistance equal to that of the conventional skin.

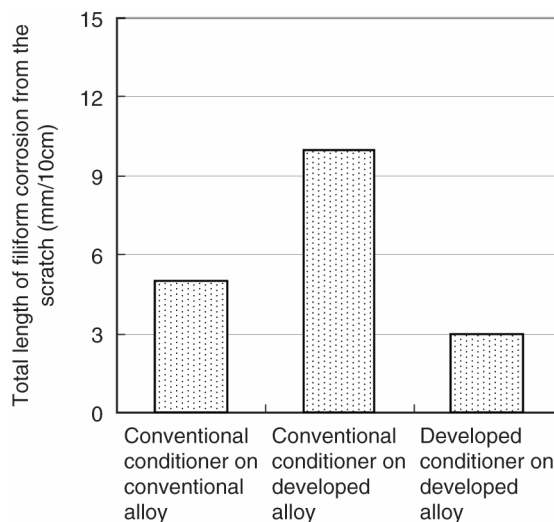


Fig. 9 Result of filiform corrosion test

7. Pedestrian Safety Technology

The deceleration characteristic of a headform impactor (shown as G_I , G_M , and G_B in Fig. 10) representing the collision of a pedestrian's head with the hood was controlled separately for the G_I region, where the hood mass plays a greater role, and the G_M region, where the hood stiffness plays a greater role. Figure 10 shows a comparison of an aluminum hood and a steel hood. In the case of the aluminum hood, G_I and G_M were lower while G_B tended to be higher. Therefore the following two measures were taken so that the hood would absorb the kinetic energy of the headform impactor as efficiently as the conventional hood:

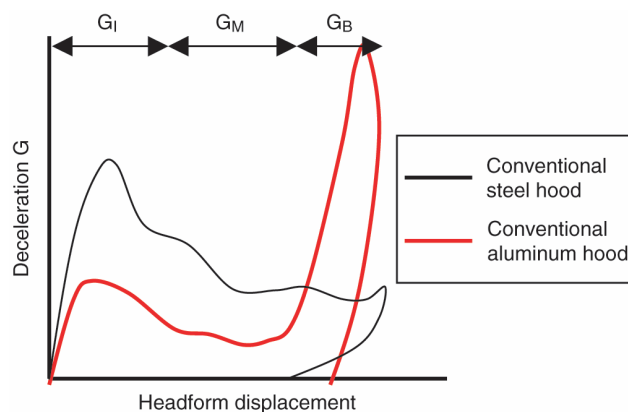


Fig. 10 Relationship between deceleration G and headform displacement

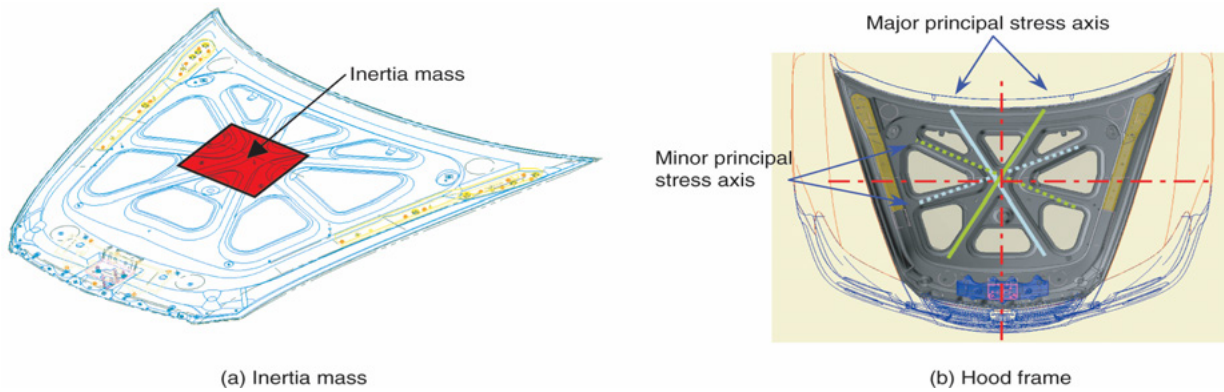


Fig. 11 Pedestrian head impact protection for 2005 model year LEGEND

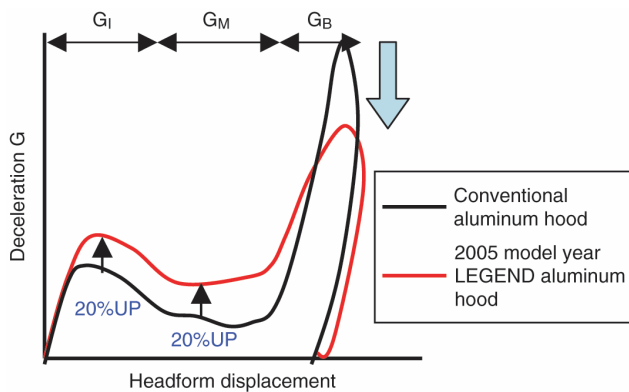


Fig. 12 Comparison of conventional hood and developed hood

- (1) A polymer sheet was added to the hood center to increase inertial mass and therefore increase G_I (Fig. 11(a)).
- (2) G_M was increased by increasing the hood stiffness (Fig. 11(b)). This was done by laying out the hood frame members so that the direction of the principal stress axis on the hood surface would coincide with frame members in the event of collision against a part of the hood with minimal clearance (clearance between the hood and the engine or intake manifold).

The above measures made it possible to increase G_I and G_M by 20%, and therefore to reduce G_B . Figure 12 shows the results.

8. Conclusion

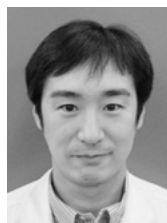
An aluminum hood that provides reduced material costs while maintaining durability and performance requirements and helps ensure pedestrian safety performance was developed for the 2005 model year LEGEND. The various technologies applied to this aluminum hood are summarized below:

- (1) For the aluminum sheet alloy, the chemical composition of the hood skin alloy was given a higher Cu impurity content in order to reduce material costs. A continuous casting rolling method was used for the stiffener alloy. This shortened the sheet manufacturing process and broadened the range of allowable Fe impurity content, making it possible to reduce material costs.
- (2) A mastic sealer that is capable of bonding both aluminum

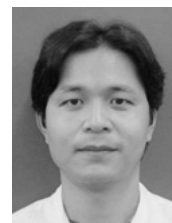
and steel was used as the adhesive. Allowing for shared use of general purpose equipment made it possible to reduce costs.

- (3) Joints were made using self-piercing rivets with greater spot weldability, making it possible to reduce processing costs.
- (4) A surface conditioner with zinc phosphoric crystal as the principal component was used for surface treatment. This made it possible to increase the crystallization rate of the chemical conversion coating. In this way even a hood skin material containing larger amounts of Cu impurities could provide corrosion resistance equal to conventional material. This made it possible to reduce material costs.
- (5) For pedestrian safety, a polymer sheet for inertial mass was added to the aluminum hood and the hood frame structure was optimized. This allowed us to reduce the peak G caused by the impact of the engine parts through the hood.

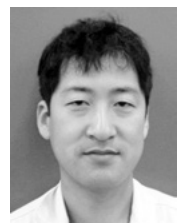
■ Authors ■



Noboru HAYASHI



Katsutoshi ANDO



Masakazu KASHIWAGI