

Bimetallic Corrosion Prevention in Hybrid Doors by Means of Watertight Structure using Low-elasticity Sealer

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ABSTRACT

Seeking to realize weight savings in vehicle bodies, Honda has developed a lightweight and high cost-efficiency aluminum/steel-sheet hybrid door. Bimetallic corrosion in the area of connection between the two metals represented an issue for this door. The difference in electric potential between the two metals would promote corrosion, raising the possibility of a decline in commercial appeal. In order to address this issue, a sealer was employed to help prevent infiltration of water. In addition to providing watertightness in the use environment, it was necessary for this sealer to possess a low elastic modulus in order to help prevent distortion from being generated in the skin panel during the sealer curing process. A watertight structure was realized through the development of application specifications using a low-elasticity sealer.

1. Introduction

Concern regarding global warming originating in greenhouse gas emissions today demands the reduction of CO₂ emissions on a global scale. For the automotive industry, the major issue is the realization of increased fuel efficiency, and a wide variety of means of reducing fuel consumption are being researched and put into practical application, including the achievement of increased engine efficiency, engine electrification, and the reduction of rolling resistance. The achievement of weight savings in the vehicle body is an important element in the realization of increased fuel efficiency, prompting automakers to replace certain parts of their vehicle bodies with low-density materials. Honda has led its competitors in advancing the realization of weight savings in automotive bodies, for example in its early mass production of all-aluminum bodies. The company is also working to develop low-cost weight-saving technologies to help enable the presentation of higher-quality products to its customers at lower prices. In the area of vehicle doors, Honda is already mass producing lightweight all-aluminum doors, but has also proceeded with the development of a hybrid door that uses aluminum only for the door skin in order to realize a lightweight door with a high cost-to-weight-reduction ratio (Fig. 1).

Normally, when two different metal materials such as aluminum and steel sheets come into contact, bimetallic corrosion becomes an issue. In an aqueous solution, the metal with an electric potential further in the base direction becomes an anode, and the speed of corrosion increases in comparison to a situation in which the metal is used in

isolation⁽¹⁾. Attempting to prevent decline in commercial appeal due to this phenomenon in the lower edge of the door, where rainwater and other fluids tend to accumulate, was also an issue in the development of the hybrid door. In seeking to prevent bimetallic corrosion, attempting to prevent contact with water is the important first consideration, and the realization of a watertight structure in the area of the joint between the aluminum and the steel sheets was therefore examined.

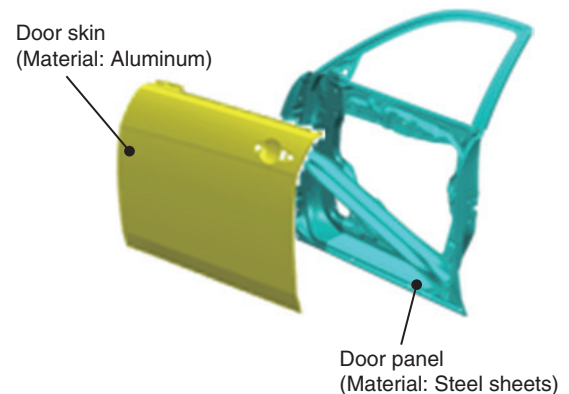


Fig. 1 Structure of hybrid door

2. Issues and Methods of Realizing Goals

Figure 2 shows the hemming structure that joins the door skin and the door panel at the lower edge of the door and the path of infiltration of water. When water infiltrates into the interior of the door, bimetallic corrosion occurs, and

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corrosion products result in the deterioration of the joint, swelling of the surface of the exterior sheet, and perforation corrosion, as shown in Fig. 3. As a countermeasure, it was therefore decided to coat the mating faces of the door skin and the door panel with a sealer to help prevent the infiltration of water. However, filling the space between the mating faces with a conventional sealer would result in distortion occurring in the door skin during production. A sealer material and an application specification that would not produce distortion were therefore examined.

2.1. Reduction of Distortion

Sealers are hardened in a baking process. In the case of the hybrid door, the difference in the coefficients of linear expansion of the aluminum and the steel sheets would result in a displacement of a maximum of 1.2 mm between the mating faces when the materials were heated. When the sealer hardens in this state, a shear force is generated in the sealer when the door skin contracts as the door is cooled. Distortion occurs because the door skin is maintained in a position in which the return force of the door skin and the shear force of the sealer are in equilibrium. Because conventional sealers have high elastic moduli and the shear force is strong, equilibrium is reached with significant displacement remaining in the door skin, as shown in Fig. 4, and this results in distortion exceeding benchmark values (Fig. 5). In order to reduce the distortion in the door skin,

it would be necessary to reduce the residual displacement of the mating faces to 0.4 mm or less. It would therefore be necessary for the sealer to be capable of responding to displacements of 0.8 mm or more. Given that the thickness of the sealer at the mating faces is only around 0.1 mm, the material would have to display a rate of expansion of 800% or more, an unrealistic figure. It was therefore decided to induce breakage of the sealer in order to reduce distortion. Equation (1) shows the breaking displacement of the sealer, and Eq. (2) shows the necessary conditions for breaking of the sealer.

$$x_B = \sqrt{\{(\epsilon_B + 1)^2 - 1\} t^2} \quad (1)$$

$$F_B = E \frac{\sqrt{t^2 + x_B^2} - t}{t} S < 76.05 \times (1.2 - x_B)^{0.56} \quad (2)$$

x_B : Sealer breaking displacement

ϵ_B : Sealer breaking distortion

t : Sealer thickness

F_B : Minimum shear force per unit length at which sealer breaks

E : Sealer elastic modulus

S : Area of sealer

A sealer with a low modulus of elasticity satisfying Eqs. (1) and (2) was selected (termed “low-elasticity sealer” below). Table 1 shows the physical properties of the sealer.

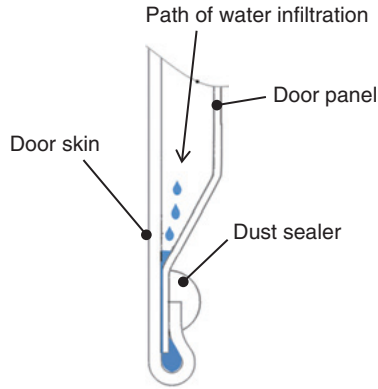


Fig. 2 Path of water infiltration into hemming structure

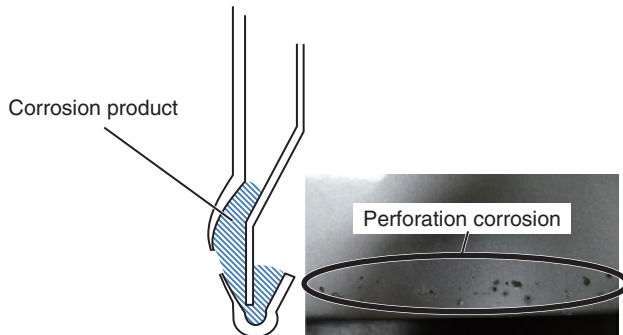


Fig. 3 Example of galvanic corrosion

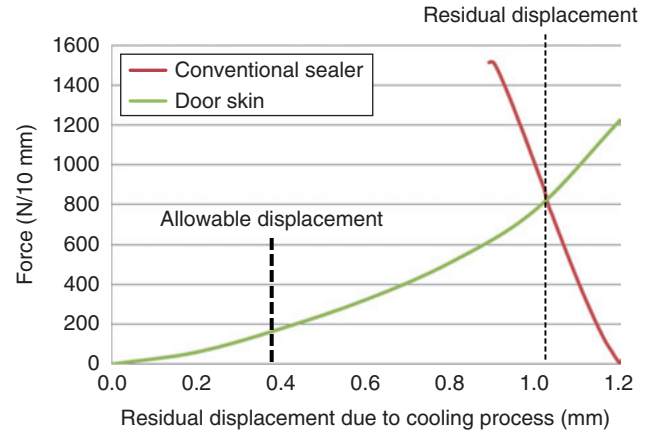


Fig. 4 Returning force of door skin and shear force of sealer

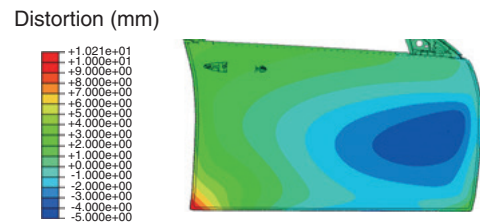


Fig. 5 Distortion in door skin with conventional sealer

Table 1 Mechanical properties of low-elasticity sealer

Young's modulus	Maximum elongation	Guaranteed elongation after degradation
0.22 MPa	200%	50%

2.2. Measures to Realize Watertightness

The sections of the low-elasticity sealer filling the space between the mating faces would be broken in order to reduce distortion. A projecting application structure was therefore considered in order to help ensure watertightness (Fig. 6). This projecting section would respond to displacement without breaking. As displacement occurring in the mating faces, it would be necessary to consider not merely displacement occurring during the baking process, but also displacement occurring during the use of the vehicle.

Both static displacement due to the difference in coefficient of linear expansion between the two materials and dynamic displacement due to the opening and closing of the door occur during use, and composite displacement resulting from these two types of displacement occurs in the mating faces. Because the degree of expansion of the aluminum door skin would be greater than that of the steel-sheet door panel in a high-temperature environment, displacement would occur in the sliding direction of the door panel away from the hemming structure of the door skin. At the maximum temperature in extremely hot regions, the maximum displacement would be 0.3 mm. In low-temperature regions, contraction would be greater in the door skin than the door panel, and displacement would occur in the sliding direction of the door panel into the hemming structure. At the minimum temperature in extremely cold regions, the maximum displacement would be 0.3 mm. With regard to dynamic displacement, the maximum displacement occurs when the door is closed hard, as shown in Fig. 7, and the maximum displacement under these conditions was found to be 0.6 mm in the sliding direction of the door panel away from the hemming structure. Therefore, the maximum displacement during use would be 0.9 mm in the sliding direction of the door panel away from the hemming structure, occurring when the door was closed hard in an extremely hot environment.

Based on the above, it was determined that the

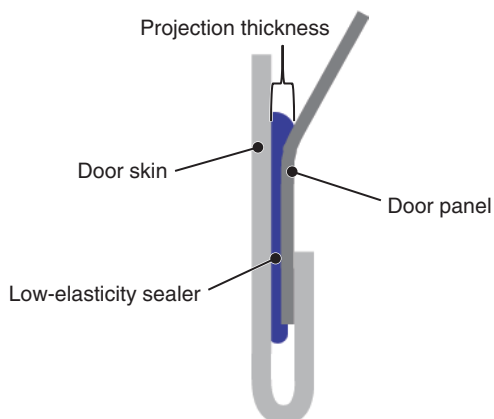


Fig. 6 Watertight structure

maximum displacement occurring in the joint section would be 1.2 mm in the sliding direction of the door panel into the hemming structure during manufacture.

As Fig. 8 and Eq. (3) show, the ability of the low-elasticity sealer to respond to the maximum displacement of 1.2 mm is dependent on the elongation characteristic of the sealer and the thickness of its application.

$$x = (\varepsilon^2 - 1)^{0.5} t_0 \quad (3)$$

t_0 : Sealer thickness

x : Sealer shear displacement

ε : Sealer rate of elongation

Because the guaranteed rate of elongation of the low-elasticity sealer was 50%, the thickness of the projecting section was set at 1.0 mm to help enable the material to respond to a maximum shear displacement of 1.2 mm.

This projecting section would also produce a shear force in the sealer of the type described in the previous section. Equation (4) shows the shear force F in the projection and the sealer at the mating faces.

$$F = E \frac{x - 0.1}{0.1} S + \int_0^y E \frac{x + \sqrt{r^2 - y^2} + r}{-\sqrt{r^2 - y^2} + r} y w dy \quad (4)$$

r : Radius of bend in door panel

y : Height of projection

w : Width of coating

Figure 9 shows the relationship between the shear characteristic of the projection during application and the return force of the door skin. The projecting section of the low-elasticity sealer is in a state of equilibrium with the return force of the door skin without breaking at a displacement of close to 0 mm. The adopted specifications made it possible to reconcile the reduction of distortion in the door skin with the achievement of watertightness.

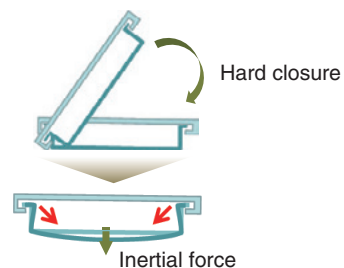


Fig. 7 Displacement by hard closure

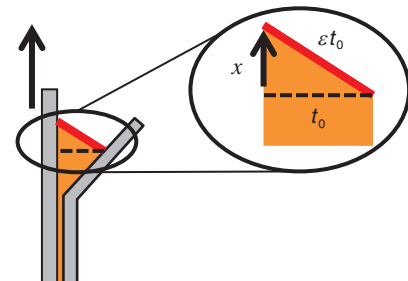


Fig. 8 Shear displacement and sealer elongation

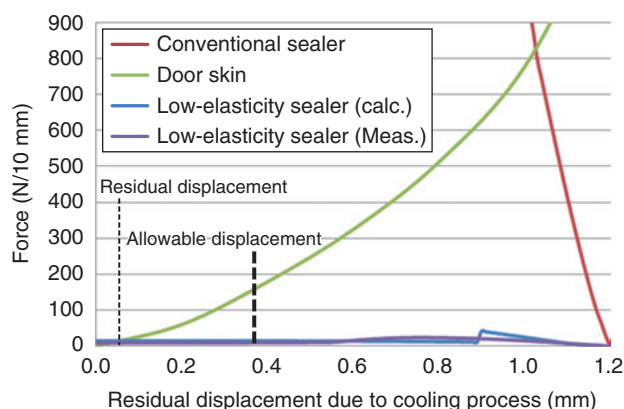


Fig. 9 Returning force of door skin and shear force of watertight structure

3. Verification Results

3.1. Verification of Door Skin Distortion with Low-elasticity Sealer

Figure 10 shows the results of measurements of distortion in the door skin for the connecting structure shown in Fig. 6, as used in an actual door. Distortion in the door skin has been reduced compared to results for a conventional sealer (Fig. 5).

3.2. Verification of Corrosion Resistance of Hybrid Door in Actual Vehicle

The corrosion resistance of a hybrid door using the low-elasticity sealer was studied in vehicle driving tests used to evaluate compound durability. Figure 11 shows an external view of the door following the test, and Fig. 12 shows a cross-section of the lower edge of the door following the test. Bimetallic corrosion has been controlled, and no reduction in commercial appeal is apparent.

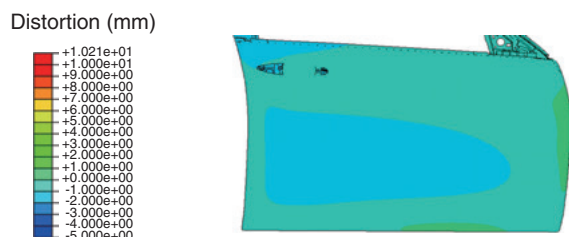


Fig. 10 Distortion in door skin with watertight structure

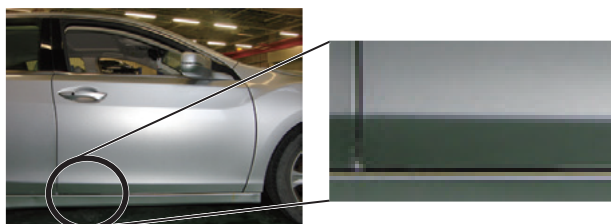


Fig. 11 Appearance after vehicle durability test

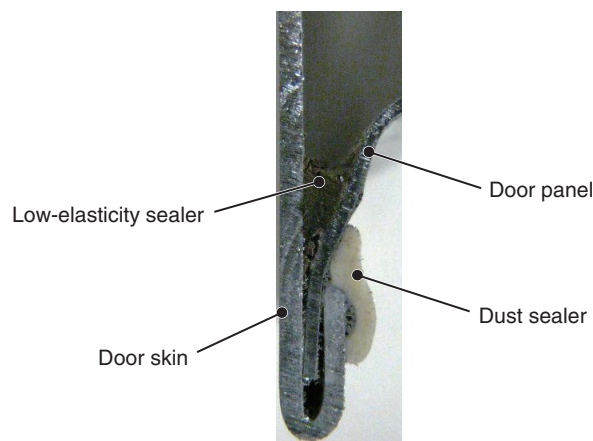


Fig. 12 Door lower edge section after vehicle durability test

4. Conclusion

Honda has developed an aluminum/steel-sheet hybrid door that uses aluminum rather than steel sheets for the door skin as a high-productivity lightweight door. To help prevent the bimetallic corrosion that would represent an issue in this project, a low-elasticity sealer that would help to control distortion in the skin panel was developed, and sealing specifications were set to assist in enabling the material to respond to displacement, resulting in a watertight sealer structure. Comprehensive vehicle durability tests verified that the developed structure provided sufficient corrosion resistance performance.

This aluminum/steel-sheet hybrid door is being employed in the 2014 new model ACURA RLX.

Reference

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