Search for a Stronger and Lighter Vehicle Body
- To Promote Energy Saving –

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A review of the history of vehicle body reveals that train cars, at their initial stage, were the direct descendants of carriages, featuring steel frames and wooden outer panels. They were mere boxes drawn by a steam locomotive. As a result of modernization, passenger cars came to be designed as mobile diesel or electric cars. This trend led to an increase in the number of passengers and the development of faster cars, which gave rise to a growing demand for safe and strong bodies. To meet this demand, fully steel-made vehicles began to be manufactured.

Fully steel-made vehicles, at their early stage, featured welded frames that helped meet a greater part of the strength requirement on the vehicle. Additionally, steel outer plates were riveted for dressing. It took much labor just to weld frames, since gas welding was mainly used in those days.

With the development of manufacturing technology, the vehicle design evolved to introduce welded outer plates that met part of the strength requirement. Also, labor for welding was reduced by reducing or thinning frames. The simplification of vehicle structure progressed further in World War II, when steel materials for non-military uses were in short supply in Japan. This helped increase efforts to lighten vehicles.

After the war, Japan entered an era of mass transportation, which saw a shift to fully steel-made vehicles at an accelerated pace. In consequence of the oil shocks, the trend changed again toward energy saving, triggering heated efforts to develop light bodies.

○ Weight Reduction by the Use of Stainless Steel

Features of stainless steel, which has long been in use, include a resistance to corrosion, a high ductility, and a potential for demagnetization. The use of stainless steel as a corrosion-resistant material for vehicle manufacture, has a surprisingly long history. One of the early uses of the metal was for the outer plates of vehicles running in submarine tunnels, which had to be resistant to the influence of salt water.

Generally, iron is assumed to be liable to rusting and corrosion. In designing a steel-made body, the plate thickness therefore had to be determined by considering a possible decrease in strength due to corrosion. However, corrosion-resistant stainless steel eliminates this problem, and thereby enables the use of thinner sheets of steel. Also, the thinning of frame members became possible as a result of the development of SUS301L, a material whose strength can be enhanced through quality modification. These developments led to the advent of a light stainless steel body.

In the manufacture of stainless steel bodies, spot welding is used to avoid weld-induced burns on the outer plate surface. Also, a convex-type machining method called beading is used to eliminate the need of straightening, which was necessary for steel-made cars; as well as of the painting of outer plates. Weight reduction has been furthered by this disuse of paint, for about 100 kg of it was conventionally used to manufacture one car.

Outer plates of a stainless steel body are finished via BG finishing, which yields a semi-glossy surface (with discontinuous polish-induced flaws in the same direction); or dull finishing which yields a dull surface (an uneven, satin finished one). Recently, BG finishing has come to be preferred, partly due to its advantage in cleaning. The typical outer plate thickness is 1.5 mm or 2.0 mm (by contrast, 1.6 mm- or 2.3 mm-thick plates are used for steel cars). The thickness of a frame material is 1.5 mm or 2.5 mm (vs, 2.3 mm or 3.2 mm for steel cars). As these figures suggest, stainless steel has contributed to reducing body weight by making it unnecessary to allow for corrosion margins.

Recently, many users who want unpainted outer plates have adopted improved manufacturing methods, such as NC-based spot welding (or programmed automatic welding) and the use of long-format materials. Our company has succeeded in achieving a greater beauty and strength in outer plate finishing, by developing a next-generation body manufacturing method based on laser welding (see p. 30).

○ Weight Reduction by the Use of Aluminum Alloy

Aluminum alloy, referred to as “light alloy” in Japan, is a typically used light metal. The melting point of aluminum alloy (approx. 600℃) is lower than those of most other materials. Accordingly, it permits the molding of complex cross sections called extruded sections, which are often used e.g. for sash frames. Aluminum alloy is generally perceived as a weak material, because it is heavily used for juice cans. However, its flexural strength per unit weight is actually greater than that of iron or stainless steel.

An early light aluminum body had a structure similar to that of a steel body, with outer plates and frames assembled via arc welding, for even this primitive technique permitted a certain degree of weight reduction. However, aluminum alloy cars of this structure were not used widely. This was because the alloy, with a high thermal conductivity and a low melting point, requires advanced arc welding techniques; and also because it is costlier than iron and stainless steel.

Subsequently, increasingly large-sized extruded sections came to be manufactured using aluminum alloy. As a result, it became possible to mold a member by incorporating part of a frame into an outer plate. This significantly reduced labor for welding required for body assembly. This structure, later called the single-skin structure, features a T-shaped protrusion provided inside an outer plate, for welding to a frame. The structure, with only a small outer plate distortion, has led to the advent of aluminum alloy cars that are unpainted, like stainless steel cars. Generally, A6N01S is used as extruded material for body; this material, with improved strength and molding characteristics, is specially designed for extrusion. A7N01S, an even stronger material, is used for underframes and entrance members that require an especially high strength.

With the progress of extrusion molding techniques, it has also become possible to manufacture large, hollow members via extrusion. This has led to the introduction of truss-shaped members of the "double-skin" structure. Cars of the double-skin structure tend to be heavier than those of the single-skin structure, because of the need to use two (front and back) outer plates. However, the former structure, with a high rigidity, permits the saving of frames. Also, it is simpler and more suitable for automatic welding. Accordingly, the use of the double-skin structure is becoming widespread, especially for the manufacture of express train cars.

○ Weight Reduction by the Use of Analysis Technology

Some foreign users want steel vehicles, e.g. in view of the ease of repair. Though stainless steel or aluminum alloy cannot be used for weight reduction in such cases, these users still want lighter vehicles. Accordingly, it becomes necessary to thin down plates and reduce frames while maintaining a required level of body strength. In the manufacture of train cars, as well as in other cases of small-quantity production, it is inefficient, and costly, to repeat trial production and load testing. Strength analysis is a very effective method to shorten time for these procedures.

In the strength analysis of a vehicle body, the finite element method (which involves dividing a complex structure into a finite number of simple elements) is generally used for calculation. In the past, when a long time was required for calculation, only side bodies were subjected to analysis, because there are no significant differences in structure among roofs or frames. Also, the analysis was used for the enhancement of amenities (e.g. the expansion of entrances or windows), rather than the improvement of strength. At present, however, the progress and widespread use of computers have made it possible to analyze an entire body, in a greatly reduced time and with better precision. Also, the focus of strength analysis has been shifting recently, from the reinforcement or further improvement of strength to weight reduction and the prevention of a decrease in strength due to a simplified structure.