Latest A-Train Railcar Enhancements

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OVERVIEW: Faced with fewer skilled workers in the future and the need to reduce environmental impacts and life cycle costs, Hitachi developed the A-train, a futuristic next-generation aluminum railcar system based on a radical rethinking of railcar materials, construction, and manufacturing. Initially placed in service on commuter and suburban lines, the A-train has now also been deployed on some express routes. The A-train features (1) a precision, high-quality aluminum double-skin body constructed by FSW (friction-stir welding), (2) fully self-supporting interior modules, and (3) an integral hollow extruded mounting rail to which the modules are fastened. In addition to providing a quieter ride, better rigidity, and improved safety, the use of FSW technology results in sleek aluminum double-skin rail cars with virtually no distortion. Adoption of a modular approach for the interior has reduced the car production lead time, simplified the work involved in refurbishing railcars, and yielded other cost efficiencies. Finally, the combination of aluminum double-wall structure and module-mounting rail fastening was designed with recycling in mind to facilitate the dismantling of decommissioned cars and the sorting of materials.

INTRODUCTION

OVER the long course of railroad history, the development of railcars has reflected the needs of society at different periods as manifested in the materials, structures, and systems used. Particularly with the rapidly changing social environment and emergence of new technologies, the demands on railcars today are becoming more challenging than ever

Fig. 1—Railcars Manufactured Based on New A-Train Concepts.
To meet the diverse requirements of various kinds of railcars, the A-train, a next-generation aluminum railcar system incorporating revolutionary new concepts, is being developed.*

Tsukuba Express EMU for Metropolitan Intercity Railway Company

817-series commuter EMU for Kyushu Railway Company

E257-series EMU for “Azusa,” “Kaiji” limited express trains, East Japan Railway Company

885-series Tilting EMU for “Shiroi Kamome” limited express train, Kyushu Railway Company

EMU: electric multiple unit
* The A in A-train stands for a number of concepts and features characterizing the new system, all starting with the letter A: advanced, amenity, ability and aluminum.

before with the need to satisfy such diverse requirements as improved safety, comfort, cost-effectiveness, and environmental considerations. Conventional structures and fabrication methods had reached the point of diminishing returns, and it really called for radical new approaches to address these modern needs. This was the challenge that Hitachi faced in developing the A-train, a next-generation railcar system based on innovative new concepts: a precision aluminum double-skin structure, and self-supporting interior modules with mounting rail fastening (see Fig. 1).

The A-train fully satisfied the initial design objectives in terms of comfort, economy, and environmental friendliness. More recently, demand emerged for better safety and crashworthiness in the event of collisions. While Japan’s railroads are supported by an advanced signaling system and a safety record second to none, accidents at railroad crossings and elsewhere nevertheless occur, and there was growing concern that design-for-safety measures be implemented to minimize the risk of injury if a collision were to occur. In addressing this concern, Hitachi not only improved the safety of the A-train when involved in collisions, but also incorporated innovations to simply the restoration and repair work after an accident.

This paper will present an overview of the development of the A-train next-generation aluminum railcar system, and highlight the safety features making the A-train cars more crashworthy than any railcars previously developed.

A-TRAIN NEXT-GENERATION ALUMINUM RAILCAR SYSTEM: CONCEPT AND FEATURES

Concept and Basic Configuration

The design, manufacture, and maintenance of railcars has always involved a fairly substantial number of skilled workers, but the demographic reality is such that this cannot be sustained. Faced with a declining birthrate, an aging population, and a diminishing pool of skilled workers, Hitachi has been working for some time on a railcar system that would permit design, manufacture, and maintenance (while of course maintaining the same high level of reliability) with fewer skilled workers.

The essential development concept was to unify the objective and means in achieving whatever it takes to satisfy the diverse needs of both passengers and society at large, and come up with a simple railcar structure that is modular and observes a pattern so it can be easily replicated.

The concept and basic configuration of the A-train are represented in Figs. 2 and 3, respectively.

Features

Comfort

The double-skin structure provides far better sound-insulation characteristics than a single-skin structure. In contrast to the small surface density of the external cladding of the single-skin, the surface density of the entire surface of the double-skin structure is practically uniform, and the entire mass acts effectively to insulate sound.

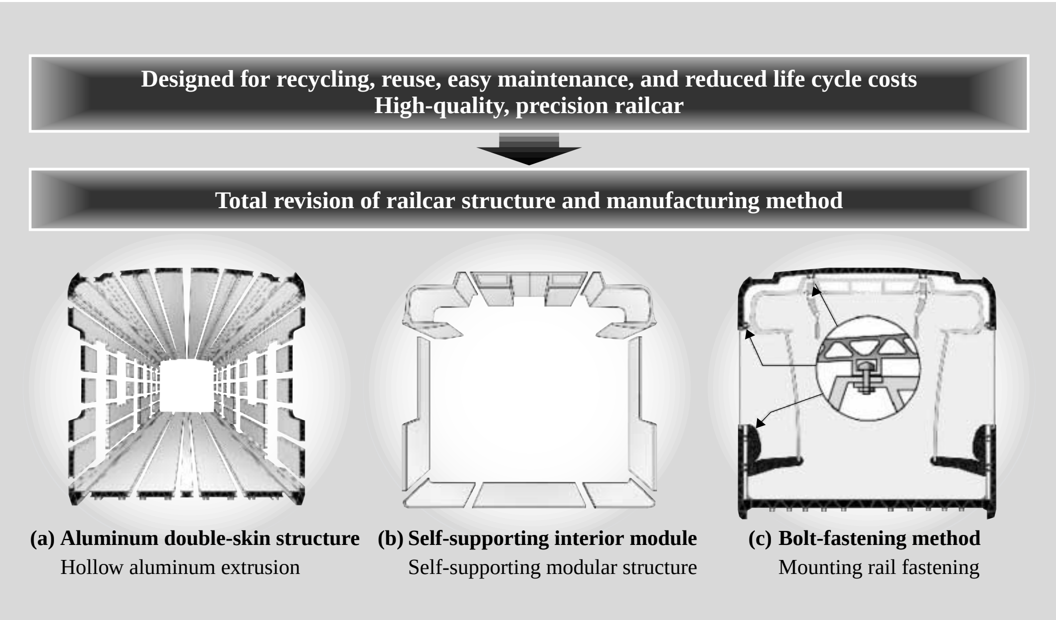


Fig. 2—Basic Concept of A-train.
The combination of aluminum double-skin structure made of hollow extruded aluminum and rigid self-supporting interior modules has revolutionized the structure and manufacture of railcars.

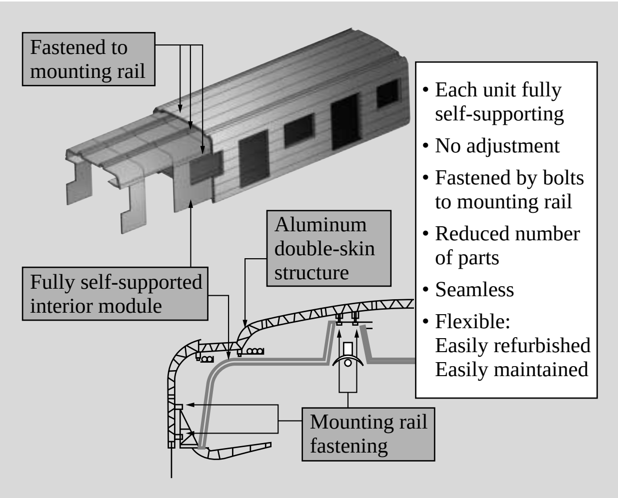


Fig. 3—Basic Configuration of A-train.
Self-supporting interior modules are easily installed and fastened with bolts in the aluminum double-skin shell that is integrally combined with the mounting rail.

Fig. 4 shows a side-by-side comparison of actual measured data for single-skin cars and double-skin cars. One can see that the overall noise level of the double-skin car is 3 to 6 dB (A) lower than that of the single-skin car (overall sound pressure), thus making for a quieter, more enjoyable experience for passengers.

Cost-effectiveness

Looking at the cost of materials alone, aluminum is more expensive than stainless steel, but the simplicity of the aluminum double-skin structure has significant cost advantages. First, the assembly of different sections can be automated and less labor translates into lower assembly costs, and second the production lead-time can also be substantially reduced. Another advantage of aluminum is that this metal has considerable residual value when the cars are eventually scrapped, and aluminum can be recycled for only about 3% of the energy required to produce new metal.

Adoption of the self-supporting modular construction method to assemble cars reduces the assembly cost even further, and also facilitates the later refurbishment of railcars. Another benefit of the modular approach is that it eliminates the need for a structural framework and allows a simple floor structure without the complexity of a joist system. This means that the structural mass of the new aluminum cars (including interior framework and floor structure) is about 5% lighter than that of the conventional stainless steel structure, and lighter weight translates into less energy needed to propel the cars.

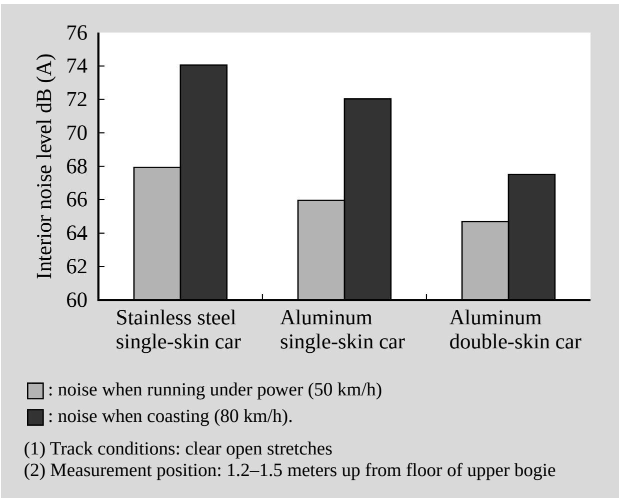


Fig. 4—Noise Levels Inside Single-skin and Double-skin Railcars (Measured on Commuter Trains).
The uniform density of the whole surface of the aluminum double-skin structure without framework means that the total mass effectively acts as sound insulation, thus resulting in a quieter ride.

Environmental considerations

The fact noted in the previous section that the structure of the A-train is lighter has environmental implications, for this means that it takes less energy to operate the train and produces fewer CO_2 emissions in doing so. It was found based on the results of an LCA (life cycle assessment) comparing the aluminum double-skin cars with stainless steel cars that the energy needed to run the aluminum cars could be reduced by 98%.

IMPROVED SAFETY IN COLLISIONS

Basic Structure

Improving the safety of railcars involved in collisions essentially involves two things: minimizing the structural deformation and damage sustained by cars, and ensuring the safety of passengers and crew when a collision occurs. It is also necessary in a collision to absorb the kinetic energy of the railcar while suppressing the impact acceleration acting on the car.

Based on the modular structure of the A-train, each car is divided into three sections: a front-end module, a central passenger compartment, and an intermediate-end module. If an accident occurs, the collision energy is absorbed by plastic deformation capability of the front-end and intermediate-end modules. This sharply reduces the impact acceleration, minimizes deformation and damage to the central passenger compartment, and thereby safeguards the passenger compartment survival zone where crew and passengers are located.

Ensuring Safety

The hollow aluminum extruded external cladding of the double-skin structure is stronger structurally than stainless steel or single-skin bodies, and thus exhibits superior collapse strength performance against compression loads in the direction of the rails and tensile strength against local loads. We have seen incidents both here in Japan and elsewhere where the weld seam of an aluminum car ruptures and this leads to more extensive damage. However, the FSW (friction-stir welding) method applied to the A-train substantially reduces this problem. We examined the toughness profiles of FSW welds and found they exhibited better toughness and impact strength than the parent metal and MIG (metal inert gas) welded joints, so we expect fewer and less serious breaks to occur in collisions and improved safety. Use of FSW and other new technologies means that the A-train aluminum double-skin structure provides enhanced safety for passengers and crew members alike.

Collision Energy Absorbed by Crashable Zone

We observed earlier that the aluminum double-skin structure of the A-train provides a high degree of compression strength. This means that when an accident occurs, the structure behaves like a rigid body, producing high impact acceleration that of course also strongly impacts the passengers, crew, and equipment. To alleviate this situation we designed the two modules on either end of the car to provide greater plastic deformation in response to a relatively low compression load than the middle section (where the passengers are located), so that a good portion of the kinetic energy from a collision is converted into deformation energy (load required for deformation × displacement amount) and absorbed, thus creating a structure — or crashable zone — that effectively suppresses impact acceleration. The amount of collision energy that a crashable zone should be capable of absorbing was determined through dynamic simulation of the way trains behave in collisions, and the crashable zone was designed to safely withstand the full range of loads and impact accelerations acting on different kinds of railcars. Fig.5 shows an example of the train behavior dynamic simulation.

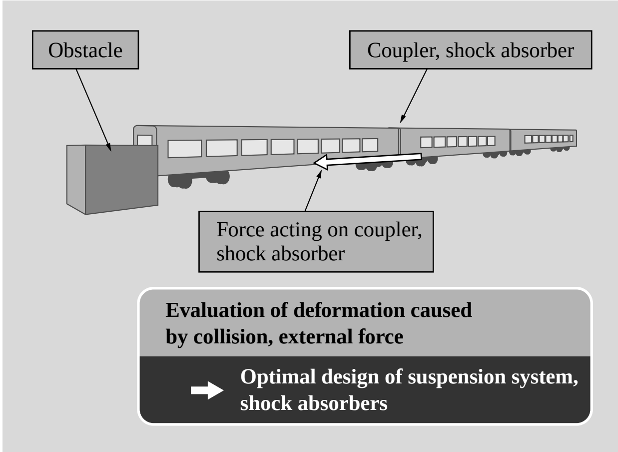


Fig. 5—Typical Dynamic Simulation of Train Behavior.
Based on typical train behavior in collisions, the amount of collision energy to be absorbed by the collision zone is set, so it can safely absorb the prescribed load and impact acceleration acting on different kinds of railcars.

In the commercial implementation of the crashable zone approach, a notch is formed at both ends of the aluminum double-skin railcars, so that the ends of the cars have lower compression strength than the mid section. Then if a collision occurs, just the ends of the car are susceptible to plastic deformation and absorb most of the impact energy. We are currently exploring a number of methods for increasing the absorption performance even more by developing frames of front-end and intermediate-end modules using high energy absorption members, and by developing a module incorporating external sheathing, interior, and all integral components (a crashable module) that can be easily bolt-fastened to the central section of the aluminum double-skin structure. With this modular approach, trains that had been damaged in accidents could be repaired and restored in a short period of time, by simply swapping out the damaged crashable module and replacing it with an identical standby module.

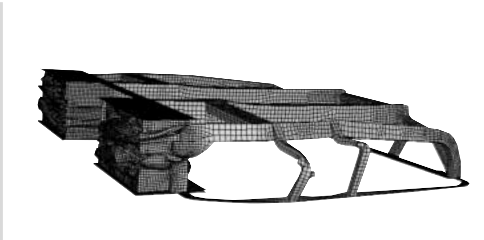
Hitachi is now using advanced elastic-plastic structural analysis techniques to develop lightweight, compact energy-absorption elements made of aluminum alloy for application to the crashable module that will be employed in A-train railcars. Fig. 6 shows an example of a front-end crashable module, and presents a comparison of mockup compression destruction test results and elastic-plastic structural analysis results.

CONCLUSIONS

In this paper we presented an overview of Hitachi's recent work on the A-train aluminum railcar system,

(a) Structure of front-end crashable module

(b) Deformation produced by mockup compression destruction test



(c) Simulation results from elastic-plastic structural analysis

Fig. 6—Example of Front-end Crashable Module.
Lightweight, compact energy-absorbing elements made of aluminum alloy have been applied. Close agreement is obtained between the results of the mockup compression destruction test and the elastic-plastic structural analysis.

representing the latest developments in aluminum railcar technology, and highlighted recent efforts to enhance the safety and crashworthiness of A-train railcars. Safety is a fundamental concern of all transportation companies. To meet the diverse needs of its corporate clients, Hitachi remains committed to providing passengers with transportation services that are not only fast, efficient, and comfortable, but also provide the highest degree of safety, and will continue work on technologies that improve the quality and safety of A-train aluminum railcars.

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