Environmentally Friendly Railway-car Technology

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OVERVIEW: As regards railway vehicles, it is becoming important to respond to the growing concerns for the global environment while satisfying the needs to provide comfort and shorten travel times. Aiming at manufacturing train cars that take account of environmental concerns, Hitachi, Ltd. has developed technologies for the high-speed "Shinkansen" — starting with East Japan Railway Company's E954-type — that raise train speed while lowering noise pollution. Furthermore, as for commuter trains, beginning with the 10000 Series for the new Fukutoshin Line of Tokyo Metro Co., Ltd., we have further advanced "A-train" technology for "cleanly" manufacturing lightweight, but extremely rigid, carriage bodywork by utilizing large-scale molded materials and friction-stir welding, and improved carriage recycleability by unifying the various kinds of aluminum alloys conventionally used into one kind. At the same time, by avoiding use of plastic resin materials (such as PVC and fiber-reinforced plastics) as much as possible — in accordance with countermeasures against fire decreed by revised ministerial ordinances — we have strengthened countermeasures against fire and poisonous gas.

INTRODUCTION

IN recent times, as concern for the environment grows, railways have been gaining attention as public transport systems with low energy consumption. Among many issues, in regard to the requirements concerning railway vehicles, on top of shortening of journey times and improving comfort, interactions along the railway line and care for the global environment are becoming ever more important.

In accepting these requirements, much work to increase speed of railway vehicles while reducing their energy consumption is being attempted by means of

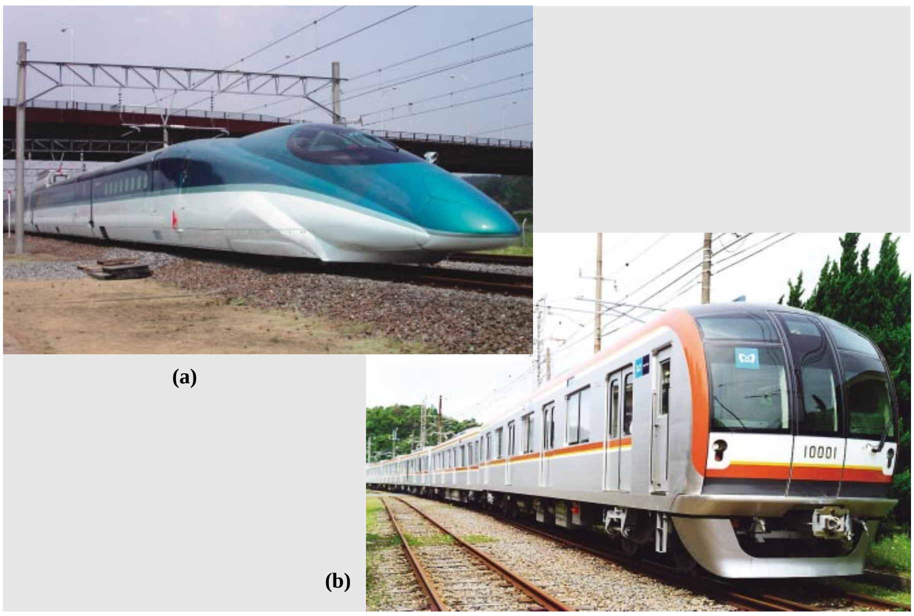

Fig. 1—High-speed Test Train of Type E954 Shinkansen of East Japan Railway Company and the 10000 Series Commuter Train of Tokyo Metro Co., Ltd.
External appearances of the Shinkansen carriages (a) and a commuter train (b) that incorporate railway-carriage systems fully accounting for environmental concerns.

reducing weight. Although Hitachi was quick off the mark to use aluminum alloys (which possess good workability and lightness) for both high-speed trains (as represented by "the Shinkansen") and the blooming number of commuter trains (such as Hitachi's "A-train"), evolution of these technologies is continuing apace.

This report presents Hitachi's new train technologies and latest solutions — first, for high-speed trains and, second, for commuter trains — that are aimed at addressing environmental concerns (see Fig. 1).

TECHNOLOGY FOR HIGH-SPEED "SHINKANSEN" TRAIN

Increasing the Speed of High-speed Shinkansen Train

As regards improving efficiency of inter-city transport by so-called Shinkansen, it is effective to shorten travel times, so it is necessary to raise train running speed. To that end, attention must be paid to environmental and safety concerns, and technical standards covering all aspects of amenity and so on must be improved. In June 2005, a test model of a new Shinkansen called the E954 Series — whose development target was a commercial-operating speed of 360 km/h (the world's highest standard) — was completed. Following that, in April 2006, the E955 Series — a type that can run on new and existing through-service lines — was completed (see Fig. 2).

The high-speed-train technologies adopted by the E954 and E955 Shinkansens that Hitachi has had a hand in developing are described in the following sections.

Raising Running Speed

To reduce weight, size, and noise of train equipment while maintaining required power for drive systems, water-cycle cooling systems that utilize air-flow generated while the train is running for cooling control equipment are adopted so that motor-driven fans (which are a source of noise) can be eliminated (see Fig. 3).

As for the train bogies, the limit of "hunting-motion" critical velocity has been increased in correspondence with raising running speed, and safety has also been maintained. Moreover, by adopting an electromotion linear actuator for suppressing left-right vibration of the train cars, responsiveness and ride quality have both been improved in comparison with conventional Shinkansen. What's more, ride quality has been further improved by softening the pneumatic springs between the bogies and car body and by alleviating the up-and-down vibration of the carriage (see Fig. 4).

Fig. 2—High-speed Test Vehicle of Type E955 Shinkansen "FASTECH360Z" (train for new and existing direct routes).
Type E955 is the Shinkansen for tying together new lines and existing lines (without the need for train transfers) aiming at a 360-km/h commercial service.

Fig. 3—External Appearance of the Main Converter of the Water-cooling System Utilizing Air-flow during Train Running.
By fitting a water-cycle-cooling system using airflow generated during train running (thereby eliminating the need for electrical air circulation), a compact, lightweight, and low-noise main converter was accomplished.

Concerns for the Environment

In regard to running Shinkansens at high speed, it is necessary to face up to a variety of environmental concerns.

As for the E954 and E955 Shinkansens, aerodynamic issues that accompany raising of maximum speed were dealt with. These include micro pressure waves in tunnels and carriage exterior noise.

The problem of tunnel micro pressure waves causes the environmental problem of noise pollution; that is to say, pressure waves are generated when a high-speed train plunges into a tunnel, and some of the waves are discharged from the tunnel when the pressure waves reaching the tunnel exit are reflected.

To reduce these tunnel micro pressure waves, the most effective method is to smooth the leading edge of the train by easing the degree of cross-sectional rate of change. However, extending the leading edge gives rise to problems that have an adverse effect on

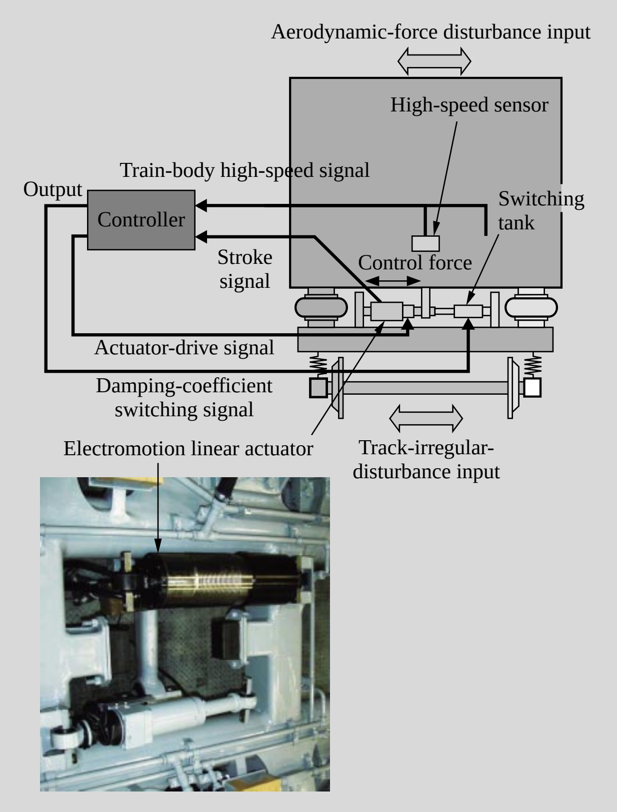

Fig. 4—Control Equipment for Preventing Shaking by Electromotion Linear Actuator.
Vibration is suppressed by means of an electromotion linear actuator for detecting vibration of the Shinkansen to the left and right.

operating facilities and passenger capacity. Accordingly, using the latest analytical methods, we determined the leading-edge shape by charting the optimum cross-sectional rate of change from the degree of aerodynamic contribution. As for countermeasures against train noise, for further smoothing of carriage-body surfaces, all-around covering between cars has been adopted, and low-noise sound-insulating covering has been used for the pantographs. Moreover, while multiple reflections occur between the soundproof barriers on along-the-line ground equipment and the train body repeatedly, noise generated from underneath the cars gets out to the outside through the sound barrier. Accordingly, by applying sound-absorbing materials to the under surfaces of the cars, this noise is absorbed, thereby reducing noise outside the train.

Improving Passenger Comfort

It is very important for passenger comfort to preserve quietness in the train car while the train is running. To improve quietness in the cars, it is necessary to improve the sound-proof characteristics of the railway cars and make sound sources from various equipment low noise. Accordingly, the E954 and E955 were developed with these approaches in mind.

In regard to improving sound absorbance of the railway cars, noise-intrusion paths in existing cars were identified. Moreover, in regard to increasing transmission loss, light, sound-absorbing materials have been inserted between the body structure of the side panels, roof, and so on and interior car panels without adding extra weight. On top of that, by mounting the main transformer (which is a source of noise and vibration under the floor) and other equipment on the train body with vibration-absorbing mounts and by adopting a vibration-blocking structure for the car-floor construction, solid-propagation sound has been reduced.

TECHNOLOGY FOR COMMUTER TRAINS

The Evolving A-train

The next-generation aluminum train system “A-train” consists of cars whose materials, construction, and production methods were drastically overhauled under the concept of lowering environmental load and cutting life-cycle costs while accommodating the forecast decline in skilled workers. It has since been adopted for various kinds of train—ranging from commuter trains up to limited-express trains (see Fig. 5).

The family of A-trains, covering commuter trains

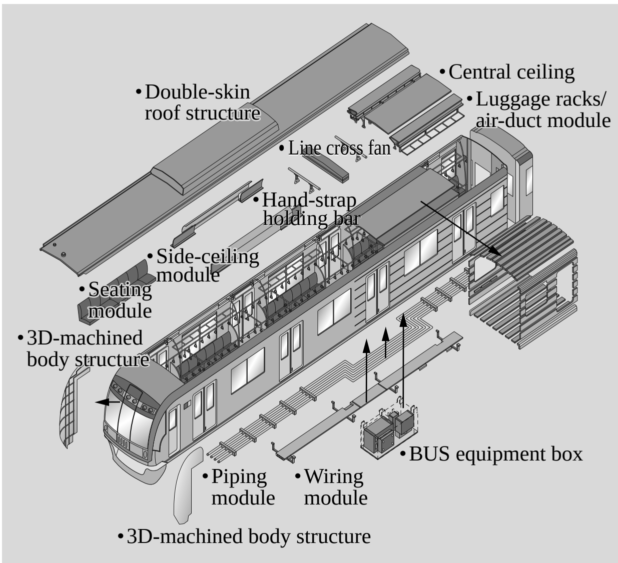

Fig. 5—Basic Structure of “A-train.”
The A-train is assembled by bolting self-supporting modules to a mounting rail integrally molded in an aluminum double-skin body structure.

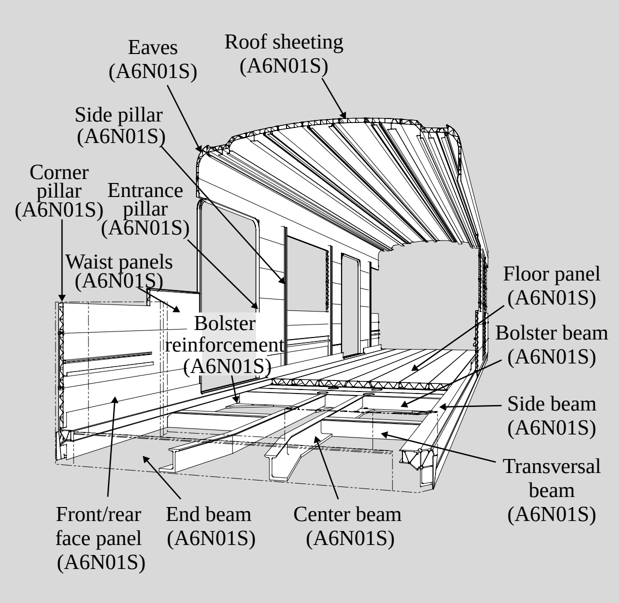

Fig. 6—Unification of Aluminum Alloys Used for Train Body.
With the exception of the double-skin body, all aluminum alloys used for the top joints, pillars, and so on are unified as A6N01S.

up to limited-express trains, has been steadily growing from 2003 up till today. Some examples are the "TSUKUBA EXPRESS" TX-2000 of Metropolitan Intercity Railway Company, the 3000-series of the Nanakuma Line of Fukuoka City Transportation Bureau, the E257 Series limited express of the Uchibo Line and Sotobo Line of East Japan Railway Company, the Tozai Line 05 Series subway train of Tokyo Metro Co., Ltd., the 10000 Series of the Fukutoshin Line and Yurakucho Line, the 2000 Series of TOYO RAPID RAILWAY, CO. LTD. (running on the Tozai Line), the Tojo Line 50000 Series of TOBU RAILWAY CO. LTD., and the Kyoto Line 9300 Series and the Kobe Line 9000 Series of Hankyu Corporation.

Furthermore, while keeping changes in the business environment concerning rail transport in mind, Hitachi is working on improving the quality of A-trains even more.

As for commuter trains, efforts are continuing to improve comfort of passenger cars. For example, aluminum-type materials and vacuum-insulating materials on the curved surfaces of ceilings are unified and attached to the double-skin construction of the roof structure to form a "triple-skin" construction, and car ceilings are heightened by changing the orientation of

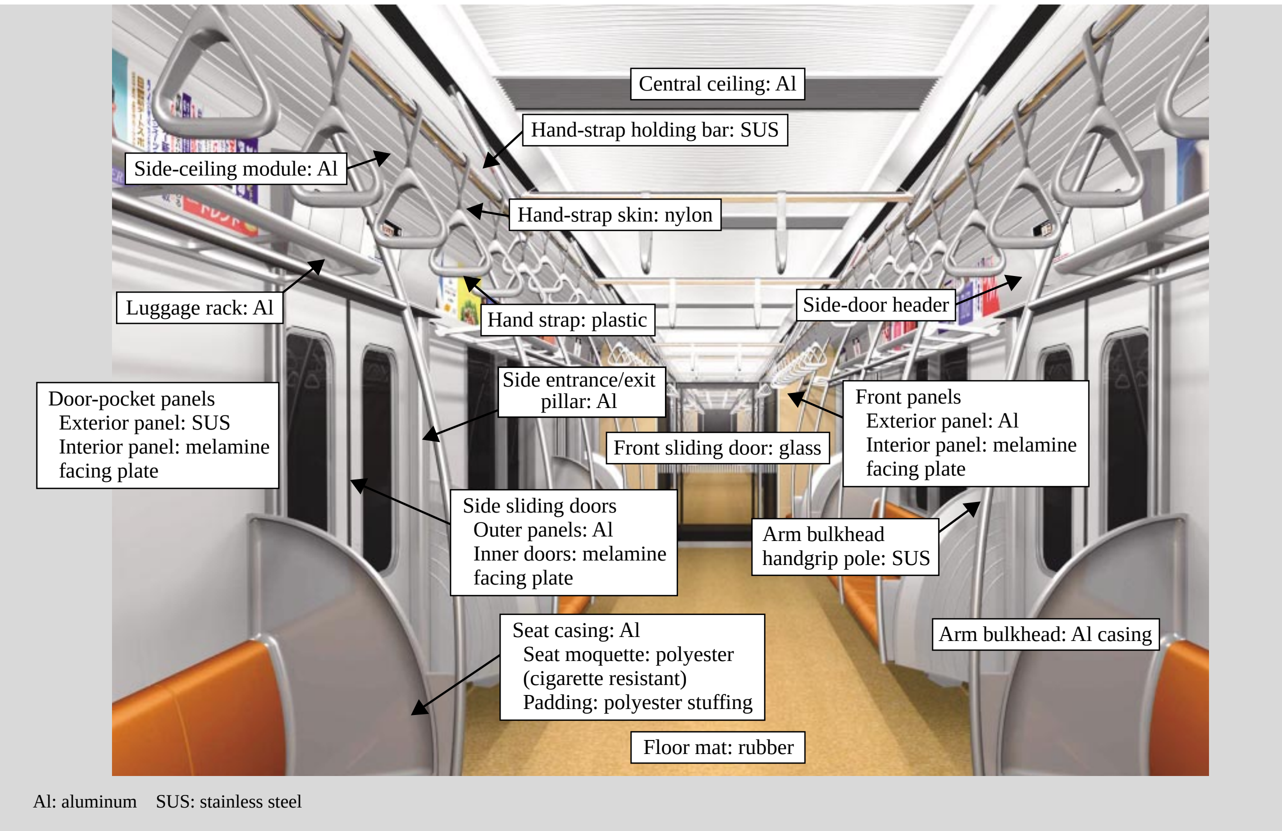

Fig. 7—Countermeasures against Fire and Noxious Gases for Passenger-cabin Fixtures.
Materials for suppressing generation of fire and noxious gas are adopted for all fixtures (from the ceiling to seating and flooring materials).

air blowers and staggering the position of air-conditioning ducts on the outside of cars in order to assure an "open-doored" interior space.

Recycleabilty improvement technology incorporated in the latest commuter trains as well as fire and noxious-gas countermeasures are described below.

Improving Recycleability

As for commuter trains, in consideration of recycleability (i.e. when trains are disposed), not only the double-skin construction but also regions that need special strengthening (like pillars and beams) adopt a unified type of aluminum alloy under a given wall thickness (see Fig. 6).

Moreover, for the materials used for the interior fittings, while using as much aluminum alloy as possible for handrails at door entrances/exits, ventilation outlets, and so on keeps down use of other metals while making sorting at recycling time easy, quality of regenerated aluminum alloys is improved. On top of that, the train body achieves "paintlessness" by utilizing high-precision and high-grade friction stir welding for the aluminum double skin as well as by eliminating under-sealing of door frames and under surfaces of bogies (owing to the excellent corrosion characteristic of aluminum alloy). As a result, recycleability is improved at the same time as environmental load incurred by painting, etc. is reduced.

Countermeasures against Fire and Toxic Gas

It is desirable to do everything possible to avoid using plastic-resin materials [such as FRPC (fiber reinforced plastics) and PVC (polyvinyl chloride)] that can generate poisonous gases like gaseous chlorine and cyanides when railway cars are involved in accidents and disasters. To satisfy that desire, by making cooling outlets inflammable by replacing FRP with aluminum alloys and by mixing aramid fiber into the cloth of seat coverings, fire resistance is further enhanced. In addition, as a countermeasure against poisonous gas, floor and holding-strap materials have been switched to rubber and nylon synthetic fibers (see Fig. 7).

CONCLUSIONS

As example solutions offered by Hitachi for railway vehicle systems supporting train services, Hitachi's efforts in regard to the environment encompassing high-speed "Shinkansens" and next-generation aluminum train systems, "A-trains," were described in this report. As for railway vehicles, it is clear from a world-wide viewpoint that Japan's technology — beginning with that in high-speed Shinkansens— is drawing much attention from many countries in Europe, Asia, and so on, and increasing global development is expected. Hitachi is taking the lead in technologies by presenting new train forms that look ahead to the varied needs of future railway vehicles. Moreover, in response to the unfailing demands for safety and reliability, we will continue striving to develop the best new technologies.

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