Development and Global Deployment of Environmentally Conscious Railway Systems

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OVERVIEW: As greater attention is paid to environmental problems, high expectations are being placed on the role of railways as a means of transport that by its nature places a light impact on the environment. Hitachi is working on technical developments that will further enhance this characteristic of low environmental burden. For diesel trains, Hitachi has developed a hybrid drive system that tests indicate will provide up to about 20% better energy-efficiency than current diesel engines and that is being developed further and introduced into practical use in Japan. Hitachi has also developed and confirmed the effectiveness of systems that make effective use of regenerative electric power on electrified sections by storing unused regenerative electric power in lithium-ion batteries so that it can be supplied back to powering trains. For carbodies, Hitachi is working on initiatives that include the adoption of lightweight energy-efficient designs that use an aluminum body structure and saving on resources by using recycled aluminum. Hitachi is also deploying environmentally conscious trains globally that incorporate these technologies.

INTRODUCTION

AS greater attention has been paid to global environmental problems in recent years such as the announcement by the former Hatoyama government of a greenhouse gas emissions reduction target of 25% compared to 1990 levels by 2020 (subject to conditions), expectations are growing for railway transport which inherently places a low burden on the environment.

In response to these expectations, there has been growing activity in the development of technology for minimizing energy consumption using techniques such as progressed system control technology and electric power storage technology. Increasing attention is also being paid to areas such as improving the efficiency of product recycling, maintenance, and similar.

In response to these expectations and hopes, Hitachi is doing its utmost to develop technologies for reducing the impact on the environment that will improve the environmental performance of railway transport (see Fig. 1). For example, technologies intended to reduce energy consumption include hybrid driving systems for diesel trains, systems for making effective use of

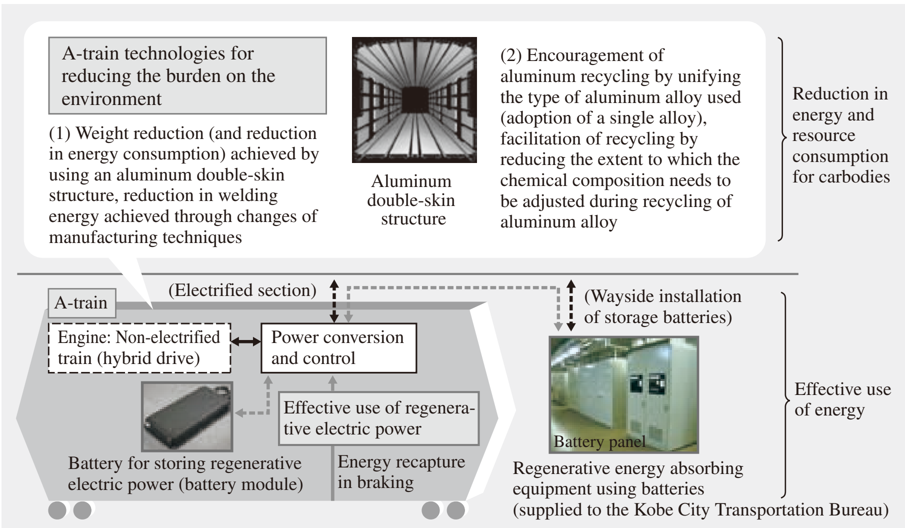

Fig. 1—Main Environmentally Conscious Railway System Technologies Developed by Hitachi.
Hitachi is working on developing technology in a wide range of different systems for further improving the environmental performance of railway systems.

regenerative electric power on electrified sections, and technologies for recycling of rolling stock include the recycling of aluminum. Use of technology for lightweight carbodies and aluminum recycling is one of the features of the A-train concept that Hitachi has been advocating for some time. Hitachi is also working on numerous other technologies that take account of the environment and Hitachi trains based on these technologies have been also adopted outside Japan in countries like the UK.

This article describes systems for making effective use of regenerative electric power and A-train technologies that take account of the environment, these being examples of technologies for reducing the burden on the environment that further enhance the characteristics of railway systems, and the expansion of sales of these technologies to the global market.

SYSTEMS FOR MAKING EFFECTIVE USE OF REGENERATIVE ELECTRIC POWER

Hitachi is developing systems that use lithium ion batteries to make effective use of regenerative electric power in accordance with user needs.

Hybrid Driving System for Diesel Railcars

Hybrid driving systems for diesel railcars powered by diesel engines can be broadly divided into two types. One is the series hybrid drive with characteristics that include simple mechanical components and easy maintenance and the other is parallel hybrid drive which can use the outputs of both the diesel engine and electric motor to drive the train's wheels and is characterized by improved energy efficiency and the ability to use lower-rated electrical components. Hitachi has developed both types of system to match user needs.

(1) Series hybrid driving system

The series hybrid driving system was developed jointly with the East Japan Railway Company and has been commercially used in Kiha E200 Type trains (see Fig. 2). The features of the series hybrid driving system produced by this development work include a reduction in exhaust gas emissions by avoiding operating the engine in rotating ranges in which fuel consumption is poor and easier maintenance achieved through measures such as common usage of the train's electrical components and cutting the number of mechanical components.

In the control field, Hitachi has developed control technologies to reduce vehicle noise by shutting down power generation by the engine when the train is stopped and until it reaches a predefined speed, as monitoring the state of charge of the secondary battery and to manage the state of charge appropriately based on the relationship between the state of charge and speed with the aim of extending the life of the secondary battery. Hitachi has also developed constant-power converter control to manage the input and output of energy in the DC (direct current) section between the converter and inverter based on the electric power and has enabled discharge and charge control to be performed appropriately. Although the performance depends on factors such as the track and running conditions, these can achieve a reduction in fuel consumption of about 10%.

(2) Hybrid active shift transmission

Hitachi developed HAST (hybrid active shift transmission) jointly with the Hokkaido Railway Company to implement a parallel hybrid drive that can use both the engine output and motor power to drive the train's wheels (see Fig. 3). This system is a next-

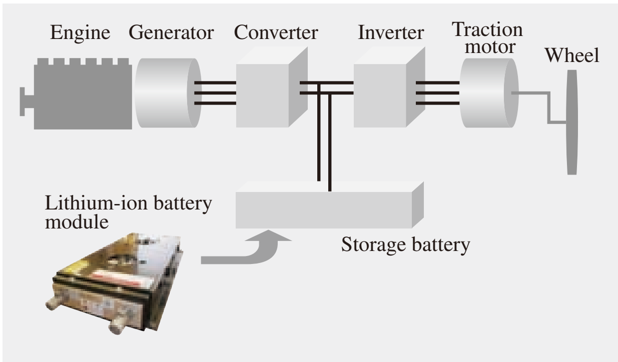

Fig. 2—Basic Configuration of Series Hybrid Driving System.
The wheels are driven by the traction motor. The storage battery unit is accompanied with a chopper panel to adjust the voltage and an auxiliary power supply as required.

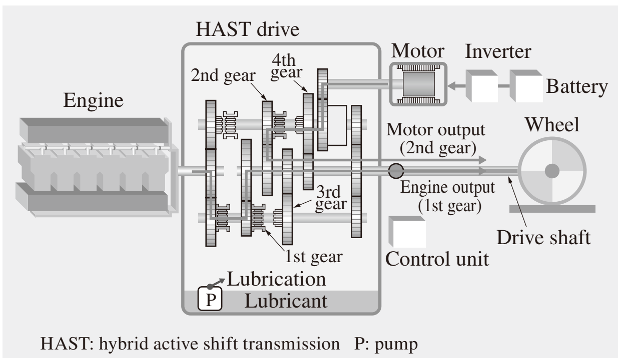

Fig. 3—Configuration of HAST Drive.
A high level of efficiency is achieved using both the output from the engine and motor power to drive the wheels, and this is expected to improve fuel consumption by 15 to 20% compared to conventional diesel railcars.

generation transmission for diesel hybrid trains that improves vehicle performance and increases efficiency while placing a low burden on the environment and is anticipated to provide fuel consumption improvements in the range of 15 to 20% compared to existing diesel railcars.

The HAST drive uses combined control of the dog clutch and motor power to achieve greater efficiency than a conventional hydraulic transmission. Like a series hybrid drive, the engine is turned off when the train is stationary to reduce vehicle noise. After the train starts to move, the engine is started when a predefined speed is reached and a level of vehicle performance in excess of the engine power is achieved by augmenting the engine with power from the electric motor. When decelerating, the electric motor is used as a generator to recharge the battery via regenerative braking. Motor control is used to synchronize the engine and drive shaft and achieve a smooth shift between speed ranges.

It is possible to upgrade an existing train to hybrid operation by replacing its hydraulic transmission with a HAST drive and adding a motor, battery, and inverter, and trials are in progress in preparation for bringing this technology into commercial use.

System for Making Effective Use of Regenerative Electric Power on Electrified Sections

A problem on electrified sections is that regenerative electric power produced by a train may not be able to be used by other trains depending on its operational circumstances. In response, Hitachi has developed a system that uses a secondary battery to make effective use of regenerative electric power even on electrified sections. The two possible configurations for such a system are to install the secondary battery on the wayside or to install it on the train and Hitachi has developed systems that make effective use of the respective features of these configurations to suit user needs (see Table 1).

(1) Wayside installation of secondary battery: B-CHOP system

Hitachi has developed regenerative energy absorbing equipment using batteries in which the secondary battery is installed on the wayside and which is called the B-CHOP system. Fig. 4 shows an overview of the system.

The equipment consists of three circuit blocks which are respectively a chopper panel, a battery panel, and a switchgear panel. The system has a redundant configuration and is designed to minimize ripple power to the feeder and secondary battery as well as other features.

To save cost, the secondary battery uses the same type of lithium-ion battery module that is used in automobiles. The chopper panel achieves highly efficient utilization and longer life by incorporating a control system for keeping the feeder voltage constant and a charging control system that reduces the charging ratio in preparation for the next charge when the secondary battery is not in use.

The system has been made into a product and supplied to the Kobe City Transportation Bureau where it is currently in use. The system has achieved energy savings of 358 MWh/year due to its being installed on long sections of track with a steep gradient.

(2) In-train installation of secondary battery: Sequential regenerative brake system

Fig. 5 shows the configuration of the equipment used in the sequential regenerative brake system. The sequential regenerative brake makes effective use of

TABLE 1. Comparison of Storage Battery Configurations

The table lists the respective characteristics that result from installing the secondary battery on the wayside or on the train.

Feature	Wayside installation		On-board installation	
Regenerative energy absorption function	Stores regenerative electric power that cannot be used by other trains.			
Ease of installation	Installation is comparatively easy provided space is available near the track.	○	Space for installing the storage batteries in the train is limited and batteries need to be installed in each train.	△
Continuity of regeneration when disconnected to power line	Not available	×	Available by storing regenerative electric power	○

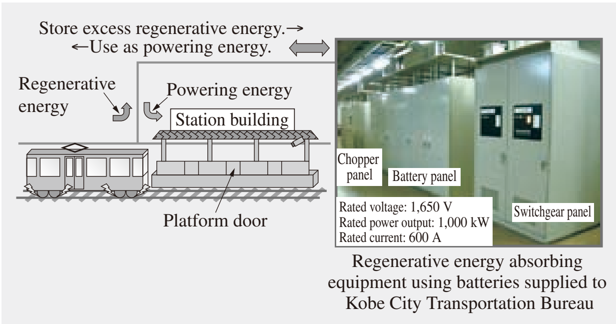

Fig. 4—Hitachi-developed Regenerative Energy Absorbing Equipment Using Batteries.

The system makes effective use of regenerative electric power by storing regenerative electric power that cannot be absorbed by storage batteries installed on the wayside and supplying the stored energy back to powering trains.

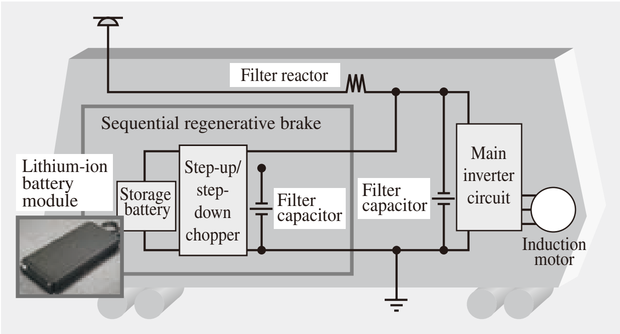

Fig. 5—Equipment Configuration of Sequential Regenerative Brake System.
This system reduces energy consumption by storing regenerative electric power that cannot be returned to the power lines in storage batteries so that it can be reused in the next powering run.

energy by storing regenerative power that is not able to be returned to the power lines in storage batteries. A step-up/step-down chopper is also used to control the charging and discharging current and handle differences between the voltages at the storage batteries and inverter.

The capacity of the storage batteries was determined so as to be sufficient to absorb all of the regenerative power in the standard case of braking to a stop (B5S). The rated voltage was set at 340 V which is approximately half the 750-V supply voltage used on the trial train. This was chosen to lower the ripple ratio on the battery current by controlling the conduction ratio (proportion of time switching element is turned on) of the step-up/step-down chopper to be approximately 50%.

Demonstrations to verify the system were carried out on an urban line in 2007 with the cooperation of the Osaka Municipal Transportation Bureau. The regenerative energy absorption function of the system improved the regeneration ratio by 11.6 percentage points to approximately 44% during off-peak times when few other trains are operating nearby to make use of the regenerated power.

ENVIRONMENTALLY CONSCIOUS A-TRAIN TECHNOLOGIES

A-train Features

Based on concepts that include reducing the burden on the environment, reducing life cycle costs, and dealing with the predicted future fall in the population of skilled workers, “next-generation A-train aluminum rolling stock system,” rolling stock to use radically revised materials, structure, and production techniques, are suitable for a wide range of different train types from commuter trains to express trains, comprise a family of models that is steadily being added to, and have been supplied in numbers that to date total approximately 1,500 units.

The body structure that provides the framework of the rolling stock features a double-skin structure. The adoption of production techniques that use FSW (friction stir welding) not only reduces welding energy use, it also reduces strain in the weld and makes a major contribution to the fabrication of unpainted rolling stock which is suitable for recycling. Similarly, adoption of a function-based modular structure and production process for parts such as those mounted in the ceiling not only allows the rolling stock to be manufactured efficiently, it also has the feature that work such as refurbishment or the dismantling of decommissioned rolling stock can be performed more easily.

Technologies for Reducing Weight and Recycling Aluminum

The aluminum double-skin structure used on the A-train is made up of hollow truss aluminum extruded shapes and is intended to reduce weight by using the minimum sheet thickness and shape required to provide the necessary strength while also having excellent recycling characteristics due to the material used being an aluminum alloy.

Recycling of aluminum rolling stock by railway operators has only just started and research is being undertaken into converting the body structure, which makes up a large proportion of the carbody, into shred scrap after the rolling stock is dismantled so that the body structure can be reused as a body structure material by materials manufacturers.

In addition to its aluminum double-skin structure, the A-train also includes reinforcing materials such as beams and pillars and it has been unified to a single aluminum alloy that does not contain different alloying elements such as zinc (see Fig. 6) to facilitate reuse by reducing the extent to which the chemical composition needs to be adjusted during recycling of the aluminum alloy.

GLOBAL SALES OF HITACHI ROLLING STOCK

In addition to the rolling stock technologies developed over time, Hitachi has also developed technologies like those described above that contribute to reducing the impact on the environment and aims to sell these products on the global market.

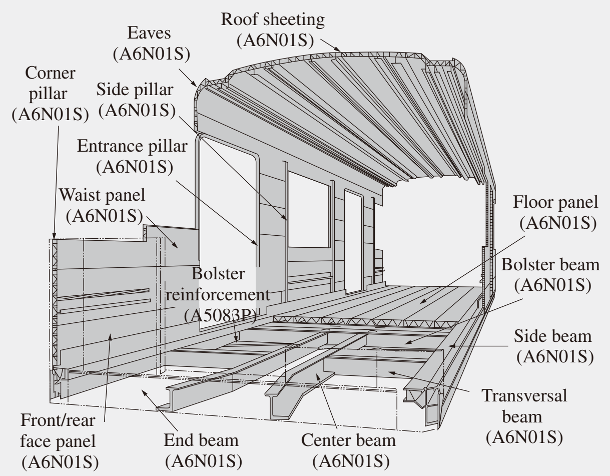

Fig. 6—Unification of Aluminum Alloys Used in Body Structure.
Hitachi has unified the A6N01S and A5083P aluminum alloys for use in components such as beams and pillars for the double-skin structure and other designs.

Hitachi received the order for the Class 395 train in the UK which is able to run on both high-speed line and conventional line in 2005 and the train formally commenced commercial operation in December 2009. The Class 395 was developed based on A-train technology. The UK contract also requires Hitachi to supply long-term maintenance services for the Class 395 trains and Hitachi Rail Europe, Ltd. has been established to handle this maintenance business. Hitachi has since the commencement of commercial operation been conducting maintenance work in accordance with train maintenance plans and delivering the trains back to the operating company with a level of quality that exceeds the requirements [see Fig. 7 (a)].

Hitachi has also been selected as a preferred bidder regarding a plan to replace diesel-powered long-distance high-speed trains in the UK due to the advantages of the numerous technologies developed in response to demand for significant reductions in energy use, significant reductions in weight compared to existing trains, and other improvements, and further because of the high reliability of the electric components for the Class 465 in the UK and the success of the Class 395. Negotiations on detailed specifications are progressing.

Overseas contracts commonly include both manufacture of the rolling stock and their subsequent maintenance and Hitachi intends to work hard to establish itself in the European railway market as well as in the UK, including as a supplier of maintenance services.

(a) Class 395 train for UK and train depot

(b) Monorail vehicle for the Palm Jumeirah Transit System

Fig. 7—Overseas Examples of Hitachi Trains.
The Class 395 train which entered full commercial operation in the UK in December 2009 (a) and the monorail vehicle for the Palm Jumeirah Transit System (b) are shown.

Elsewhere, Hitachi has also adopted the aluminum double-skin structure for monorail vehicle carbodies and has developed a vehicle for the Palm Jumeirah Transit System in Dubai in the Middle East [see Fig. 7 (b)]. As a new symbol of Palm Jumeirah Island, the monorail has been kept busy as a means of transport for visitors to the island and residents since it entered service in April 2009.

CONCLUSIONS

This article has described systems for making effective use of regenerative electric power and A-train technologies that take account of the environment, these being examples of environmentally conscious technologies that further enhance the characteristics of railway systems, and the expansion of sales of these technologies to the global market.

Technology for reducing the burden on the environment is one of the important elements in supporting the widespread use of railways as a means of transport. As a total integrator of railway systems, Hitachi intends to continue working on technology development to meet these expectations by combining the various technologies of its group companies.

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