Interpretive Article

Toward Creation of a Railway Car Meeting the 21st-century Requirements - Development of AC Train

Mitsuyuki Osawa
Advanced Railway System Development Center, Research and Development Center of JR East Group

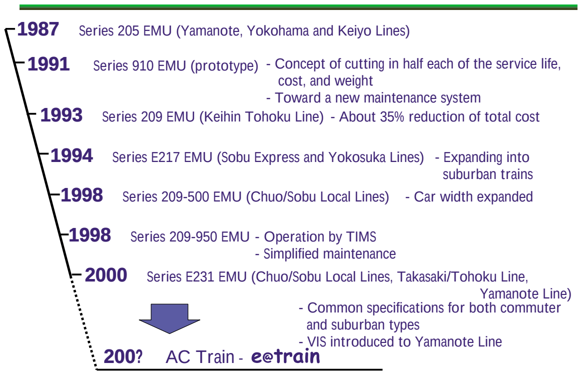
The intermediate term business concept "New Frontier 21" of East Japan group incorporates a research and development program aiming toward the construction of a new "e@train" that provides new services meeting diversified passenger requirements at a lower cost with improved safety and higher accuracy. According to this program, we have been committed to developing an "AC Train (Advanced Commuter Train)", a car that makes such an "e@train" a reality. We have recently completed construction of a prototype car that incorporates a great variety of technological elements. This car is currently undergoing various assessment tests. This article introduces the overview of this car.

1 Background of AC Train development

The East Japan's commuter trains have been developed as shown in Fig. 1. The bodies of these cars are made of lightweight stainless steel while those of the conventional cars such as Series 103 and 201 are made of conventional steel. New cars have a bolster-less truck, while conventional cars have a truck with bolster (swing bolster device). These modifications have contributed to a substantial simplification and reduction in weight. The most important one of these cars is Series 901 (Series 209 as a mass produced product) that has been developed according to the concept of "half the weight, half the service life and half the price". The traction motor of Series 901 has been changed from the conventional DC motor to an induction motor, and the MT ratio (ratio between the driving cars and trailers) per 10-car trainset from 6M4T to 4M6T. New technologies that later became the standard have been introduced into the bogie, including technologies for a bolster-less bogie of the axle beam structure characterized by reduced number of component parts, "a control transmitter" with control commands converted into digital form, "an electric door unit" and others, with the result that a substantial reduction in life cycle cost has been achieved. After that, the main circuit element of the controller was modified from GTO to IGBT due to the progress in the development of power electronics, contributing to further improvement in efficiency and cost reduction.

An intelligent car has been developed as follows: The initial device that was merely for monitoring the equipment operation status was improved and turned into a system for digital transmission of control commands. In Series 209-950 cars, this technology culminated in an integrated car information management system called the TIMS (Train Information Management System) where functions including automation of the inspection before departure from depot were improved and the amount of through-cables between cars was reduced about 80 percent

Fig. 1 History of the Development of Commuter Train



The Series E231 which are being made to put into service as a suburban commuter train is the result of all these technologies. Major improvements have been achieved to meet the requirements of the rolling stock such as cost reduction, improved reliability, improved passenger services, energy saving, improved ecology.

Ten years have passed since Series 901 was developed. More than 3000 cars of so-called New Series have already been put into service (as of the beginning of 2002), and further improvements are required. However, each element of technology has already reached a substantial phase of maturity, and further improvement is considered difficult in terms of extension of the current technologies.

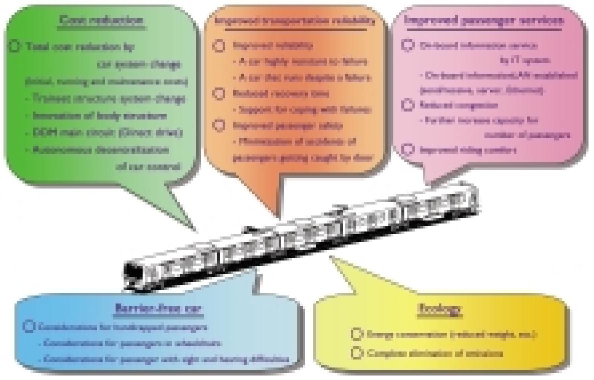
To eliminate this bottleneck, we have taken an innovative approach including fundamental reappraisal of the conventional car toward a car meeting the 21st-century requirements. This effort has resulted in the development of the AC Train.

2 Concept of development

From the viewpoint of business management, the 21st century car must satisfy the requirements for cost reduction, improved passenger services and improved transportation reliability. To meet them, the AC train was developed on the basis of two major factors; (1) System Change and (2) Utilization of IT (Information Technology).

From the viewpoint of community requirements, the car must satisfy the need for a barrier free car and ecology-conscious car as social requirements, therefore we have made the maximum use of existing technologies based on the concept of “a user-friendly and environment-friendly car.”

Fig. 2 Concept underlying the AC Train



3 Overview of the development

(1) System change

In the development of the AC Train, we started by reexamining the basic structure of the car. Thus, an articulation system was adopted in the car body structure. A double skin structure and outside hanging door were utilized, and a direct drive motor (DDM) was adopted as the traction motor. This is mainly intended to cut down on costs.

On one hand, the articulation system provides the advantages of cost reduction such as reduction in the number of car devices for each trainset, and improved traveling comfort when traveling along the curve. On the other hand, however, it has the disadvantages of increased axle weight, and complicated work in separating the car from the bogie. No commuter train using the articulation system has been adopted on a high occupancy rate line like JR East's lines. However, we have adopted an articulation system because a new maintenance system for each trainset has already been adopted in a new series of cars due to recent dramatic advances in reducing the weight of cars and improved maintenance techniques.

Further, the aluminum double skin structure allows the number of man hours in the manufacturing process to be cut down. For such reasons, this structure is commonly used in limited express trains. But in the commuter trains that are provided with many doors, this advantage could not be easily employed. In the AC Train, however, this problem is solved by eliminating the door pocket structures and using the outside hanging doors. At the same time, we made further efforts to develop a car body structure using a double skin panel made of stainless steel material. The outside hanging door structure expands the width inside the car, and is expected to increase the space for passengers with the effect of the space of the articulated portion.

Another major system change is found in the adoption of the DDM as the traction motor. In the conventional car, torque was increased via a gear installed at the intermediate position to transmit the power of the traction motor to the axle. The DDM allows the motor rotation to be transmitted directly to the axle, without using a gear. Thus, the problem to be solved in the adoption of the DDM is to increase the motor torque and to reduce the load of the motor weight applied to the axle. The AC train uses a synchronous motor provided with a powerful built-in magnet, instead of the conventional inductor motor. Introduction of the DDM was made possible by improving the runner joint with the axle. This improves the power efficiency and decreases the noise.

(2) Use of IT

IT as the key technology of today has been effectively utilized over an extensive range including "improved transportation reliability", "cost reduction" and "information services".

In the precise railway transport system in the metropolitan area, top priority must be placed on "improved transportation reliability". To meet this requirement, the car reliability must be improved. Especially, it is important to eliminate fatal car failures that may lead to the possibility of serious transportation failures. Looking at the cases of recent railway car accidents from this viewpoint, it can be seen that the main circuit and controllers of the door device and safety device preventing train collisions (ATS-P) are very important. To meet these requirements, the AT Train is based on the concept of "autonomous system decentralization" and "mutual control backup".

The configuration of the conventional rail car systems such as the main circuit system and brake system has been moving toward integration and centralization of functions, mainly to cut costs. However, this method has the disadvantage that the impact of a problem in one part affects all others. Adoption of a redundant system such as duplex system will solve this issue, but involves higher costs. This contradiction is solved by the AC Train that is based on the concept of "autonomous system decentralization".

The traction motor is characterized by adoption of a synchronous motor and a 1C1M where one controller controls one motor. It allows operation to continue even if a problem has occurred. The auxiliary power unit (SIV) has been developed to permit parallel synchronized operation control of two units. They incorporate the self-diagnostic function and automatic emergency treatment operations to the greatest extent practicable. Further, an autonomously decentralized brake independent for each bogie is also being developed, although this is not mounted on the current AC Train.

The multiple control units that are installed in the trainset, such as ATS-P control unit, door control unit (LCU) and brake control unit (BCU) are based on the "mutual control backup system" where a failure of any one unit is compensated for by other units, and the command is given by transmission of information. These systems are intended to provide a fault tolerant car that minimizes the effect of a failure.

As a control information system of the AC Train, we have developed the AIMS (Advanced Train Information Management System), an improved version of the above-mentioned TIMS. This system is intended to achieve high cost performance of the car control information system, using general-purpose transmission technology. Data transmission within the trainset is based on the Ethernet as a global standard transmission technique, and transmission within each car is based on LON Works as one of the general-purpose communications chips. This reduces the wiring inside the car and improves the subsequent system expandability due to the use of general-purpose technology. In the event of a failure, this system allows the on-board data (failure information, forward image information of the driving cab, etc.) to be sent to control headquarters by a data transmitter/receiver unit.

In the field of information service, a new approach is being made to the VIS (Visual Information System) of Series E231 that is currently in service on the Yamanote line. Information can be classified into two categories; mass information and private information according to the content, and uni-directional information and bi-directional information according to the form of distribution. The existing VIS can be said to have created the environment for uni-directional information and mass information. However, information-environment needs are moving toward bi-directional and private information, as in e-mail and Internet access. To achieve the goal of ensuring that "the information desired by a passenger can be provided at any time at any place", the AC Train is provided with an on-board service-based LAN incorporating a transmitter/receiver unit and a server for communicating with control headquarters. Further, the environment required for information service (ATISS: Advanced Train Information Service System) has been established. Using this system, our development activity is moving ahead to provide information services for commuter trains as well as for express trains.

(3) Rail cars that are both user-friendly and environment-friendly

In order to meet the rapid progress of those communities with increasing numbers of senior citizens and to assist participation of the handicapped in social activities, the railway system is expected to create an environment for easier use of the railways. Our cars have been provided with a great variety of devices aiming at achieving this objective, for example, by installation of LED text signboards and toilets for wheelchair-bound passengers. The following innovations have been added to the AC Train:

The AC Train is provided with (1) a "wheelchair slope" that provides a slope from the car to the boarding platform so that passengers in wheelchairs can get in and out of the car easily, and (2) a "wheelchair step" that adjusts the distance between the platform and car interlocked with the open/close operation of the door. Further, the floor height of the car is 1165 mm, 15 mm lower than that of the conventional car.

Adoption of an outside-hanging door solves the problem of level difference found in the case of the door rail. For the benefit of the passenger with sight and hearing difficulties, vocal and visual indications are given to give notice of when the door has been opened or closed. Color arrangement in the car is based on universal design.

The 21st century is said to be the age of environmental awareness, and commitment to ecology is a social mission imposed on each business firm, presenting a major challenge in technological development. To achieve further energy savings, the AC Train has adopted a highly efficient DDM, and has realized a reduction in car weight. To ensure complete elimination of emissions, the AC Train uses more easily recyclable materials and structure mainly for the floor and interiors.

4 Test program

The construction of the prototype AC Train car was completed toward the end of last year, and it has been put through various tests on the Saikyo and Kawagoe lines since February this year. Running stability and powering/braking performances have already been tested, and planned performances have been verified. In the future, we are planning to carry out a durability running test, to assess various technologies introduced, and to start research on commercialization and mass production.

The constituent technologies having been introduced in the AC Train have finally reached the stage of commercialization in terms of costs and the like, due to the progress of various technologies such as IT. Accurately assessing the rapidly changing situation, we are committed to meeting challenges on an advanced level toward realization of a car meeting 21st century requirements.

Fig. 3 Overview of AC Train development and test status

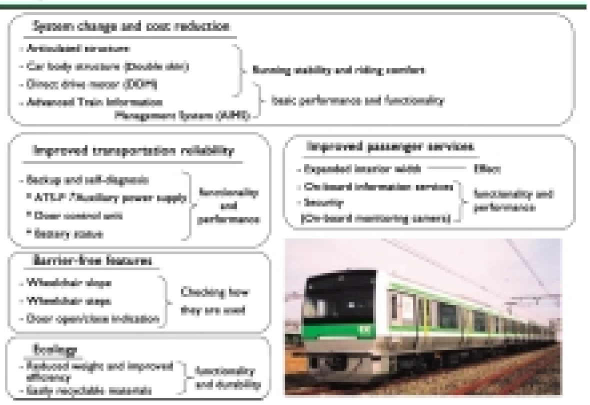


Fig. 4 Overview of AC Train Structure and Facilities

Information service (limited express type car)

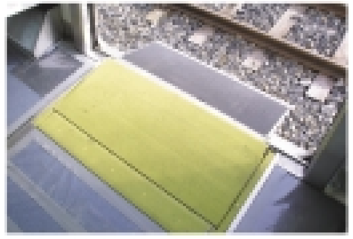
Enlarged cab space

Comprehensive LCD indicator and gauge panel

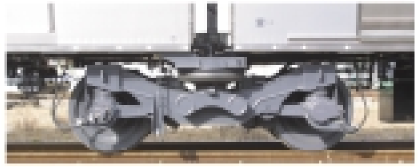
Outside hanging door

Information service (commuter type car)

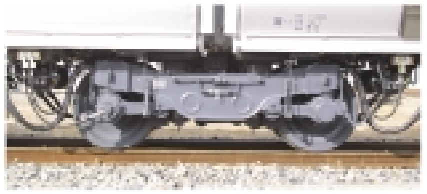
Appearance of ACTrain
Two cars at the front side are made by aluminum and the following three cars by stainless.
The leading car is 16.5 mm long and each of the intermediate cars is 13.4 m long.



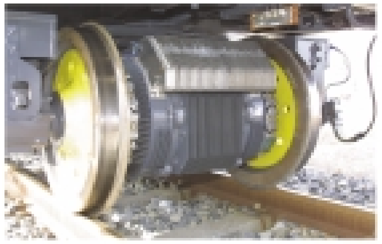
Slope for wheel chairs



4-point air spring supporting articulated bogie



2-point air spring supporting articulated bogie



DDM (direct drive motor)

Double skin stainless panel

Step for wheel chairs