First 100% Domestic Low-Floor Tram

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1. Introduction

The first 100% domestic independent wheel type low-floor tram started its service operation on the streets of Hiroshima City on March 30, 2005. The tram, named "Green Mover max," turned into reality, overcoming diverse problems over a time period of 5 years since its concept took root. This paper throws light on the details of development and outline of the tram (vehicle).

2. Concept of development

The Green Mover max was developed under a joint project involving Mitsubishi Heavy Industries, Ltd. (MHI), Kinki Sharyo Co., Ltd., and Toyo Denki Seizo K.K. in addition to Hiroshima Electric Railway Co., Ltd., as an advisor in the field of operation service. The 4 companies mustered up their efforts in the development and manufacture of LRV (Light Rail Vehicles) matching with Japanese landscape and Japanese society using Japanese technologies.

Three points were listed as the concept of development: (1) Ultimate, (2) User friendly and (3) Urban. The initial letters of these points were used to name the project: "U3 Project." In the U3 project, MHI took over bogies, brakes, and inner/outer riggings; Kinki Sharyo focused on design, car body, articulations, and driver's cabin; while Toyo Denki Seizo took responsibility for electric parts and control and drive units.

3. Background of development

The new-generation urban traffic system LRT (Light Rail Transit) is drawing attention as a city symbol transport system that is comfortable and friendly not only to environment but also to people. Especially, the high-performance, stylish and barrier-free low-floor tram, well beyond the concept of an existing tram (street car), has already been introduced in Europe and North America, with its effectiveness highly evaluated. However, the European manufactures are ahead of Japanese makers in terms of the technologies for independent wheel bogies, so that the 100% low-floor tram introduced to Japan was limited to the vehicles manufactured by foreign manufacturers or partially manufactured by domestic makers by adopting foreign technologies. This gave rise to problems of operability and maintenance, and the development of domestic vehicle befitting with the use in Japan was an immediate need and long-expected item.

The first 100% low-floor LRV developed with Japanese technology has the vehicle length 30 m and is composed of 5-car (3-bogies) configuration. As for the bogies, MHI was involved in the project from development, design, manufacture to verification processes of the bogies based on the achievements of "Technical Research Institute for Low Floor LRV Bogie" established by Land, Infrastructure, and Transportation Ministry, realizing a wide range of traveling performances such as barrier-free character, low noise, low vibration, low speed, and high speed.

4. Development of technology for independent wheel bogie

The key to the development of 100% low-floor LRV was the bogie with an independent wheel system. Normally, the left and right wheels are connected with a shaft, which determines the floor height. Therefore, an independent wheel system was adopted for our bogie. The electric-powered bogie (**Fig. 1**) had a motor and drive unit installed to the outer side of the wheel. The adoption of the new bogie system led to realization of floor height 330 mm (passage section 360 mm), enabling step less boarding into the car.

Further, the bogie section intruding into the passenger cabin was covered with seats to make the cabin comfortable. In addition, the bogie structure was made compact to allow the aisle width of 880 mm, 50 mm wider than the LRV manufactured by foreign manufacturers. Moreover, the motor-less bogie (**Fig. 2**) where no motor is installed was subjected to special design, resulting in drastically increased width of aisle up to 1120 mm and thus contributing to smooth movement of boarding and alighting passengers while ensuring wider and unobstructed view from the passenger room. Further, the number of seats on the bogie could be made 20% larger than that of an imported LRV. Elastic wheels were adopted for the bogie to reduce noise and vibration. As for brakes, three types were used – electric, hydraulic, and rail – to allow mode change with less shock to bring the car to a safe stop under any conditions.

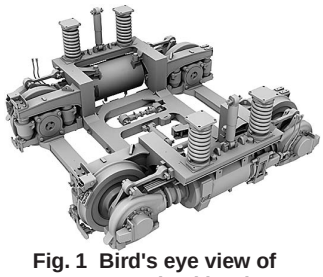

Fig. 1 Bird's eye view of motorized bogie

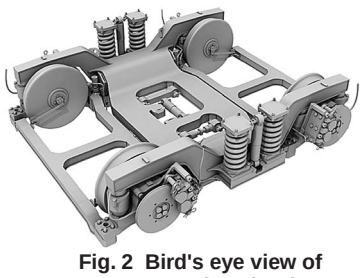

Fig. 2 Bird's eye view of motorless bogie

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5. General specifications for vehicle

Table 1 shows the general specifications for Green Mover max. The vehicle main body is equipped with Train Information System (TIS), with the monitor mounted on the driver's stand (control platform). Thus the driver's stand console was made compact, the switches were centralized, the settings were made possible by using monitor and the support measures for driving and maintenance were taken such as maintenance and trouble indications, etc., with a view to reducing the work load of the driver who has to do both: taking care of the service and drive.

The vehicle control system adopts individual motor control system using a VVVF inverter unit with high energy performance and the difference in rotational speed of the left and right wheels due to the 100 kW motor installed outside the driving bogie (4 units/1 train) and the unbalanced torque due to the wheel radius are absorbed to ensure outstanding running performance.

The car body is made of steel in view of the tram running on the road with other vehicles and paying attention to the safety, stiffness, maintenance and so on. Thanks to the thorough measures taken for reducing the weight, the car with strong and light body has been realized. In the 5-car, 3-bogie configuration, the train-set has the central cars as floating cars, with the articulations for connecting each car body ensuring high reliability while being light in weight, compact in size and needing little maintenance.

6. Vehicle design

The vehicle was designed to have a soft, roundish front-end shape to provide a fresh feeling, and friendly flavor to the passenger as the new domestic low-floor vehicle. The interior design, based on the concept of comfortable space, put maple, the symbol of Hiroshima, as the motif for the inside and outside of the car body to give a tone of local characteristics required of a street car.

7. Thorough verification of technology

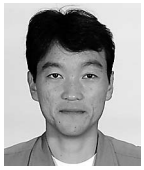
To verify the vehicle riding efficiency, MHI built a special 900-m long test trail rail track at the "Plant and Transportation Systems Engineering & Construction Center" in the company's Wada-oki Plant. A thorough verification of technologies was carried out in this test track to realize development of a vehicle with outstanding performances. In the tests, we verified acceleration/deceleration performance and safe running performance by measuring the car body behavior and the strength of bogie and car body parts. We also measured the riding quality, noise inside and outside the car, air-condition capacity and so on to verify the riding comfort and efficiency. Through these verifications, the first 100% domestic low-floor LRV was proved to have enough competitiveness against the LRV made by foreign manufacturers.

Table 1 General specifications for vehicle

Configuration		5-car 3-bogie, low-floor vehicle
Number of passengers	(people)	149 (56 seats provided)
Weight	(t)	33.9
Size	(mm)	L 30 000 x W 2 450 x H 3 450
Floor level and low-floor rate	(mm)	360 (exit/entrance 330), low-floor rate 100%
Electric mode	(V)	DC 600
Track gauge	(mm)	1 435
Maximum running speed	(km/h)	60
Acceleration	(km/h/s)	3.5
Normal deceleration	(km/h/s)	4.8
Emergency deceleration	(km/h/s)	6.0
Main control unit		2-level IGBT-VVVF inverter, regenerative and generation blending brake system
Brake unit		Mechanical (hydraulic) brake system, regenerative and generative brake, safety brake (track brake), deadman's device
Main motor		3-phase squirrel cage induction motor 100kW x 4 units
Bogie		Shaftless independent wheel bogie

8. Conclusion

As described above, the 100% low-floor LRV Green Mover max largely differed from existing vehicles in many ways and needed a wide range of verification tests. We are determined to make further improvements in technology and skill, so that it may be introduced as the city transportation system in different parts of Japan and overseas. Finally, we would like to extend our gratitude to Hiroshima Electric Railway Co., Ltd., Technical Research Institute for Low Floor LRV Bogie, Kinki Sharyo Co., Ltd., and Toyo Denki Seizo K.K for their valuable cooperation and guidance in the development of the first 100% domestic low-floor LRV.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