China's First Urban Monorail System in Chongqing

Taketoshi Sekitani
Motomi Hiraishi
Soichiro Yamasaki
Takayuki Tamotsu

OVERVIEW: On the hilly roads in the center of Chongqing city in China, traffic congestion composed of buses, taxis, and private cars is particularly bad, and the exhaust fumes from this traffic is continuing to worsen atmospheric pollution. As a public-transport measure to address this pollution problem, a straddle-type monorail has been introduced. As the first urban monorail introduced in China, the Chongqing monorail was opened to the public on June 18th, 2005. As a major partner in the Chongqing monorail project, Hitachi manufactured and installed two prototype trains (with a total of eight cars) and their mass-production bogies, electrical equipment, and points and crossing equipment. After that, 19 mass-production monorail trains (with a total of 76 cars) were manufactured and implemented by Changchun Railway Vehicles Co., Ltd in technical cooperation with Hitachi. The main features of this monorail train are as follows: large urban monorail cars, completely painted exteriors of aluminum car bodies to protect against acid rain, a VVVF (variable voltage, variable frequency) traction inverter, and fiber-reinforced-plastic seats and stanchion poles used inside cars.

INTRODUCTION

AS the largest industrial city in China's south-western region, Chongqing is in the seat of the economy and communications for the upper reaches of the Yangtze River. In March 1997, Chongqing City became the fourth city to come under direct control of the central Chinese government. In a municipal area covering 82,400 km^2 with a population of 32 million people, the urban area of Chongqing City covers 315 km^2 with a population of 3.3 million people. As regards public transportation in the Chongqing urban area—consisting of trolley busses, buses, taxis, etc.—it has

Fig. 1—The 1000-series Monorail Train Delivered by Hitachi and in Operation in Chongqing City Center.
The monorail plays a vital role in transporting citizens around the urban transport network of Chongqing.

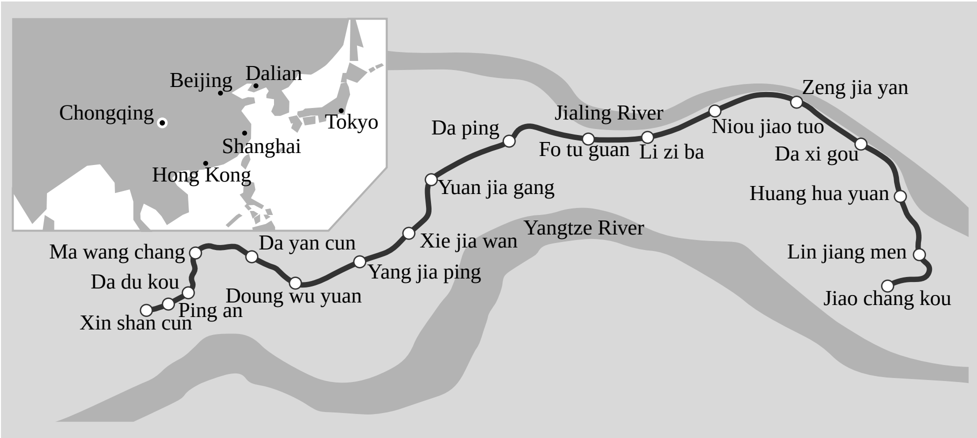

Fig. 2—Map of Chongqing Monorail No. 2 Line. Covering the No. 2 route from Jiao chang kou to Xin shan cun—following 18 km of precipitous terrain—this straddle-type monorail handles such a route with good hill-climbing ability and sharp-bend capability while making little noise.

became an urgent task to reduce atmospheric pollution caused by traffic congestion and exhaust emissions.

In 1992, the Japan International Cooperation Agency (JICA) dispatched an inspection team to this area to perform an FS (feasibility study) in collaboration with Chinese authorities. As a result of this study, it was decided to construct a straddle-type monorail, since its good hill-climbing ability and sharp-bend capability combined with low noise pollution are suited to the route conditions in the Chongqing area. In technical cooperation with the Changchun Railway Vehicles Co., Ltd.—one of the foremost railway manufacturers in China—Hitachi implemented the rolling stock as well as set up the points and crossings for the main line of the monorail. In addition, construction of the 37-km-long No. 3 line, linking Chongqing International Airport with the city center, has also started.

In the meantime, drawing attention from throughout China as one way to reduce traffic congestion and address environmental issues, the Chongqing monorail is under constant investigation.

In the rest of this paper, the main features of the Chongqing Monorail No. 2 Line are described in detail.

OVERVIEW OF CHONGQING MONORAIL NO. 2 LINE

A route map of Chongqing Monorail No. 2 Line is shown in Fig. 2. The line opened for business is the 12.5 km of double track between Doung wu yuan and Jiao chang kou (13 stations, comprised of 10 elevated stations and three underground stations with an average distance between stations of 1 km), which is the first commercial phase of the Jiao-Xin Line (covering 18 km from Jiao chang kou to Xin shan cun). The minimum radius of curvature of the track is 100 m, maximum gradient is 50‰, and the minimum radius of curvature of the train depot is 50 m.

Situated in the upper floors of a high-rise block in Da ping Station, an integrated government office housing an operations room and other management departments runs the monorail system. Moreover, the platforms of the three underground stations are fitted with screen-type safety doors.

At present, second construction phase of track between Doung wu yuan and Xin shan cun is under way, and when it is completed, 5.5 km of track with five elevated stations will be added. The assumed passenger volume (one way for the one-hour peak) that can be transported was taken as 12,600 people for four-compartment trains in the initial period, 23,000 for six-compartment trains the medium term, and 32,000 people for eight-compartment trains in the future. The length of the station platforms—which can accommodate trains with up to eight compartment—is 120 m.

CHONGQING MONORAIL ROLLING STOCK

Overview of Rolling Stock

Rolling stock comprised of 21 trains (making 84 cars) was manufactured. Two prototype trains (eight cars) and the bogies for 10 production trains (40 cars) were manufactured in Japan, and the 19 bodies of production-quality trains (76 cars) and the bogies of nine trains (36 cars) were manufactured at Changchun Railway Vehicles Co., Ltd. under license from Hitachi. Based on the specifications of metropolitan monorails in Japan, the specifications of the Chongqing monorail were defined in consideration of the environmental conditions in Chongqing and Chinese domestic production. The specifications of the rolling stock are

TABLE 1. Main Specifications of Monorail Cars

As a four-compartment train with an aluminum body, the monorail is lightweight. Based on the specifications of monorails that Hitachi has successfully implemented in Japan, the specifications for the special features added to meet the requirements of Chongqing monorail.

Items	Specifications	
Type	Large-scale straddle-type monorail	
Vehicle type	Electric car with double axle bogie truck	
Organization	4 car permanently coupled	
Passenger capacity	Mc vehicle: 151 persons; M vehicle: 165 persons (Chinese standard)	
Electrical system	DC: 1,500 V	
Track dimensions	Width: 850 mm; height: 1,500 mm	
Loading capacity	Axle load 11 t (max.)	
Performance	Acceleration: 3.0 km/h/s	
	Deceleration	Normal: 4.0 km/h/s
		Emergency: 4.5 km/h/s
Maximum gradient	60/1,000 (design value)	
Minimum curve radius	50 m (at center between tracks)	
Main electrical specification	Three-phase cage-type induction motor (105 kW × 12 units for each train)	
Control unit	VVVF traction inverter	
Brake unit	Electric-command-type electro-pneumatic straight air brake with regenerative brake	
Signal protection	Continuous train detection system and cab-signal automatic train protection	
Communication equipment	Train wireless	
Operating system	ATP two-man operated	
Low-voltage power source	85-KVA SIV (2 units per train)	
Collector	Sliding collection from the side of trolley wire	
Ventilation units	Roof-mounted inverter control system (8 units per train)	
Emergency exit	“slow down” handles (1 set per compartment)	

Mc: control motor
M: motor
DC: direct current
VVVF: variable voltage, variable frequency
ATP: automatic train protection
SIV: static inverter

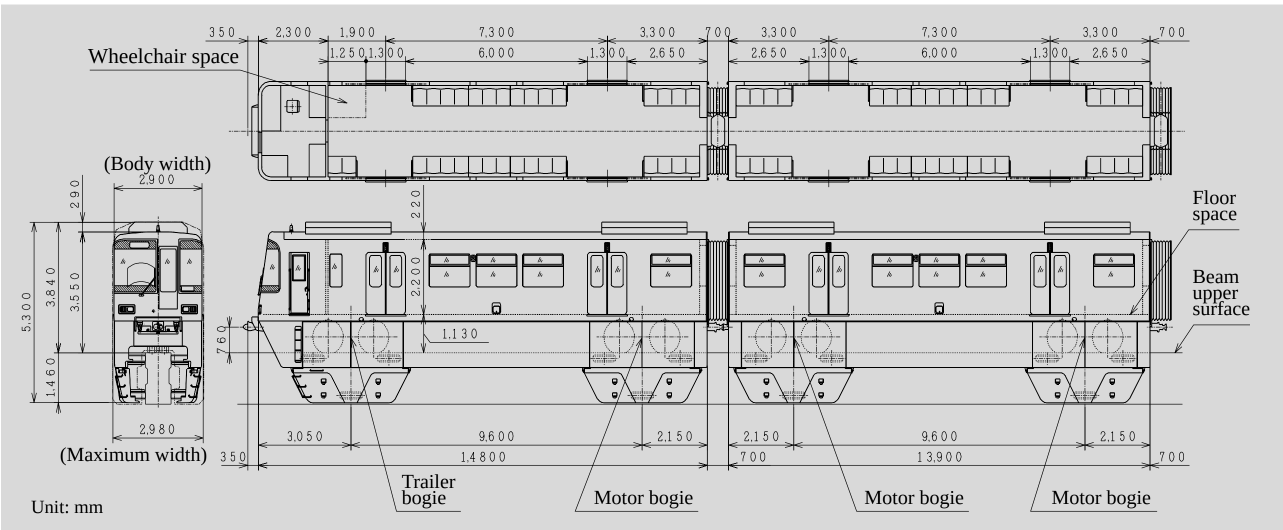

Fig. 3—Train Form and Dimensions.
Total length of the train (four compartments in order: Mc1-M2-M3-Mc2) is 60 m. Not only playing a key role in the transportation network but also adding aesthetic appeal to city centers, the monorail is expected to carry the burden of converting Chongqing into a new urban area.

listed in Table 1, and its format and dimensions are listed in Fig. 3.

Main Car Body

Extruded aluminum is used as the material for the train body, and the roof and sides are composed of a single-skin structure. The exteriors of the aluminum car bodies are painted to protect against acid rain. As for the acid-rain protection, not only is the coating selected carefully but also the structure right down to the end sections of the coated parts is taken into consideration. Special features of the body interior are FRP (fiber-reinforced plastic) long seats and stanchion poles installed inside the cars. As an air-conditioning system for handling Chongqing's torrid summer heat, two air conditioners (each with a cooling capacity of 19,000 kcal) are installed in each car of the monorail train.

Bogies

Based on the two-axle bolster-less bogies used for monorails in Japan, a coating specification for countering Chongqing's acid-rain environment is adopted for the bogies. As for the track tires—which are steel-cord rubber ones containing nitrogen—two are fitted per axle. And to allow easy tire changing, the tires are supported on the bogie frame by means of a cantilever system, and puncture-detection devices for measuring tire pressure and auxiliary wheels made of solid rubber are also fitted. Moreover, the running tires and horizontal tires used are products that have been successful in Japan.

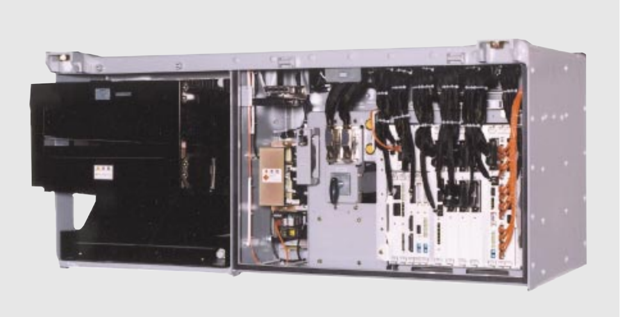

Fig. 4—External View of VVVF Traction Inverter.
A pulse-length-modulation three-level inverter using an IGBT (insulated-gate bipolar transistor) for the semiconductor circuit elements is utilized. By using vector control for finely controlling torque for each bogie, ride quality and track adhesion performance are improved.

MAIN SPECIFICATIONS OF ELECTRICAL EQUIPMENT

Main Circuit-control Unit

Based on the VVVF traction inverter that has been a success in monorail systems in Japan, the control unit is also protected against acid rain. In addition, as the monorail uses rubber tires on its axles, the elastic behavior of the tires and mechanical vibration from the electrical equipment, as well as suppression of their effects on the electrical control systems, have been carefully considered.

Moreover, control systems and vector-control technology—accomplishments that have been amassed from our experience of monorails in Japan—are utilized. And by improving the accuracy of torque control, a more stable torque output has been achieved, even at times of sudden changes in starting resistance such as immediately following start-up (when the largest mechanical vibration is easily generated).

The main features of the VVVF traction inverter are summarized as follows (see Fig. 4).

(1) As for the connections to the main electric motors, two motors are connected in parallel with one VVVF traction inverter; three of these inverters are configured as one unit. In case of a control-unit breakdown, to ensure operation of the monorail continues, each of the inverters can be disconnected so as to assure redundancy in the system.

(2) As for the body of monorail cars—insulated against ground electric potential—to reduce interference of electromagnetic fields (i.e. induction interference) with signaling equipment, a three-level inverter system is applied, and by using a correction value for carrier frequency at low speeds, generation of noise is suppressed.

(3) To cut down on maintenance costs, the inverters are fitted with a self-diagnosis inspection function, which allows input parts and control outputs of various sensors to be confirmed, thereby improving the efficiency of inspection.

Auxiliary-power Unit

As an auxiliary-power unit, for supplying AC (alternating current) power to the air-conditioners, etc., an 85-KVA static-type converter is used. Three kinds of output power—namely, three-phase 380 V, DC 110 V, and DC 24 V—are supplied according to the different loads on each car.

Monitor Control Unit

A monitor control unit, with functions for recording and conditions and operation status of the devices inside the monorail cars, is utilized. This unit is composed of a display panel installed in the driver's cab, a CPU (central-processing unit), and terminals installed in the middle car. The CPU and terminals are connected to the main electrical equipment in the cars by a current-loop transmission system, and they collect car-status record data and event record data from each device. The collected data are then displayed on the panel in the driver's cab. Moreover, the event record data can be sent from the CPU to be read out on a PC of a maintenance engineer in such a way that makes analysis of abnormal events easy.

ATP/TD Unit

In the case of this monorail system, an on-board signal stoppage system is adopted. The main features of this system are summarized as follows:

(1) ATP receiver

As regards the ATP receivers, by means of ATP track-based devices, train position status of an approaching train and track-setting conditions are transmitted to the train as a speed-limitation signal via an induction loop [ATP/TD (train detection) loop] set up continuously along the ground. This signal is continuously received and decoded by antennas fixed to the roof the train. That is, while lighting up on-board signal lights in the cab, it carries speed-limitation and stop information from each ATP control unit.

(2) TD unit

The TD unit transmits a high-frequency TD signal (indicating the train location) from an antenna on the car roof to the ATP induction loop set up continuously along the ground beside the track.

(3) ATP control unit

The ATP control units are train-protection devices that are linked to signaling gear on the ground controlled according to relative distance between one train and the next. While the ATP speed-limitation signal corresponding to the track conditions is displayed in the cab, the train is automatically stopped or is slowed down according to that speed limit, thereby assuring safe train operation. As for the ATP speed-checking, train speed detected by a speed generator and the ATP speed-limitation signal received from the track-side ATP units are compared, and in the case that the train speed exceeds the speed limit, an ATP braking command is output, and the train is automatically slowed down.

CONCLUSIONS

This paper described the features of the Chongqing Monorail No. 2 Line—China's first urban monorail.

In regards to infrastructure (like track beams and pylons, switches, and stations) and non-infrastructural elements (like signals and communication equipment, electrical-power facilities, and control systems) for monorail systems, Hitachi has been accumulating over many years extensive knowledge as a "system integrator." From now onwards, we will continue to push forward with the implementation of such monorail systems—overseas as well as in Japan—that make full use of this know-how.

In conclusion, in regards to signal protection, we are working in close cooperation with THE NIPPON SIGNAL CO. LTD., and in regards to general systems, we have received valuable guidance from the Japan Railway Technical Service (JARTS). Accordingly, we would like to express our deep gratitude to both these organizations.

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ABOUT THE AUTHORS

Taketoshi Sekitani

Joined Hitahi, Ltd. in 1969, and now works at the Monorail Systems Integration Department, the Transportation Systems Division, the Industrial Systems. He is currently engaged in the planning of monorail cars that include switches.

Motomi Hiraishi

Joined Hitachi, Ltd. in 1974, and now works at the Kasado Transportation Systems Product Division, the Transportation Systems Division, the Industrial Systems. He is currently engaged in the designing of the monorail cars and bogie trucks. Mr. Hiraishi is a member of The Japan Society of Mechanical Engineers (JSME).

Soichiro Yamasaki

Joined Hitachi, Ltd. in 1981, and now works at the Mito Transportation Systems Product Division, the Transportation Systems Division, the Industrial Systems. He is currently engaged in the designing of traction control system.

Takayuki Tamotsu

Joined Hitachi, Ltd. in 1998, and now works at the Mito Transportation Systems Product Division, the Transportation Systems Division, the Industrial Systems. He is currently engaged in the designing of on-board operation control systems.