Research on Scheme Selection of Rapid Low-floor Light Rail Vehicle

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Abstract. At present, there is no rail transit in China that can directly connect the main urban areas and satellite cities without passengers transferring halfway. In addition to the problem of passenger transfer, the construction of transfer stations presents a challenge to an already land-scarce city. In order to solve this problem, this paper introduces the status quo of rapid light rail technology in China and other countries, compares and analyzes the technical characteristics of rapid LRV, and finally puts forward suggestions on the selection of China's rapid LRV scheme in the future.

1. Introduction

The development of cities brings not only rapid economic growth, but also problems such as increased population, environmental pollution, resource depletion, and reduced urban carrying capacity. How to make the harmonious coexistence of urban development and human, environment, transportation and resources is the main goal of the current urban development process, and as a means of transportation carrying the operation of the city is the main meridian of urban development. The use of low-energy, low-pollution, high-capacity urban transportation is the preferred direction of urban development transportation. Low floor light rail is to meet these requirements, become the new darling of urban development. At present, China 's urban rail transit is entering a period of rapid development. Different cities have formulated different development strategies according to local specific conditions. Different types of rail transit are being built or planned. Even the same city can not only choose a single type of rail transit. Therefore, China 's urban rail transit will show a new trend of diversified development. In foreign countries, in addition to the subway and urban express railway, some small and medium-sized rail transit is being concerned, such as monorail transportation system, new transportation system, small section subway with white line motor, normal magnetic levitation transportation system and light rail transportation system described in this paper. As a link between urban and suburban areas, for example, in urban centres, rapid low floor light rail vehicle can operate in parallel on footpaths where private cars are prohibited from entering; to the outskirts, it runs on a dedicated track; it can also be driven into the existing railway lines to play its role as a means of urban transportation in a more flexible and diverse form. In addition, the construction cost of light rail lines is low and the construction speed is fast.

At present, with the acceleration of urban-rural integration, the personnel exchanges between the main urban areas and satellite cities in China are becoming more and more frequent, and people’s demand for faster public transportation between the two places is becoming stronger and stronger [1,2]. However, at present, there is no rail transit directly connecting the main urban area of the city and the satellite city in China, which leads to the need for multiple transfers for passengers to and from the two places. In addition to the trouble of transfer, the construction of transfer stations has also brought challenges to cities with tight land use. In order to solve this problem, a new rail transit mode, which was born in Karlsruhe, Germany in 1992, has attracted attention. The trains used in this operation mode can run across the network between the urban trunk line and the urban low-floor tram network, and can directly enter the main urban area from satellite cities, county towns, remote suburbs and other places without midway transfer. This not only provides convenience for passengers, but also saves the area of the station. This kind of train is called "tram-train" abroad. According to the characteristics of the train, we call it "rapid low floor light rail vehicle" (hereinafter referred to as "rapid LRV"). [3-6]

In this paper, the basic requirements for the selection of fast light rail include the characteristics of fast speed, strong carrying capacity and few vehicle modules. In addition, the appropriate scheme should also make the vehicle have the characteristics of low floor trams and urban trunk vehicles, combined with the international cutting-edge technology and development trend to select.

2. Features of LRV

As a new operation mode of rail transit vehicles, LRV has the following significant characteristics compared with urban trams:

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2.1. High speed

The mixed right of way is usually adopted in the city, and the station spacing is short. Suburbs usually use independent road rights, and the distance between stations is long. In order to improve the travel speed and shorten the travel time, the maximum running speed of the rapid LRV is usually 80-100 km/h, while the maximum running speed of the urban low-floor tram is less than 70 km/h.

2.2. Less vehicle modules

In the case of the same length, the vehicle module of the rapid LRV is less than the low floor tram module, as shown in Figure 1. It is not only beneficial to maintain the motion stability and smoothness of the vehicle at high speed, reduce the noise in the vehicle, but also reduce the number of through lanes and workshop hinge devices, and reduce the cost of procurement and maintenance [7].

2.3. Strong carrying capacity

Under the premise of the same vehicle length, the vehicle module is small, the number of bogies is large, and the carrying capacity of the rapid LRV is stronger than that of the existing low-floor tram, as shown in Figure 1.

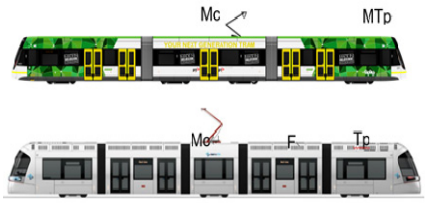
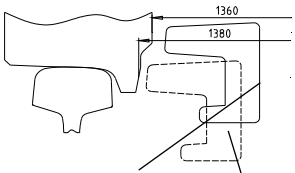


Fig. 1. Comparison of low-floor trams and rapid LRV with the same vehicle length

2.4. Double-track system

The groove rail track is usually used in the city, and the inner distance of the wheel back is usually 1380 mm. The city generally uses existing lines or abandoned railways [7,8]. The rail is a T-type rail, and the inner distance of the wheel back is usually 1360 mm (1353 mm in China). In order to achieve cross-line operation, the tread needs special design to meet the requirements of the inner distance of the double wheel back, as shown in Figure 2.



Turnout rail protection of urban trunk line

Turnout rail protection of urban tramway

Fig. 2. Position relationship between rapid LRV tread and guard rail in cross-line operation

2.5. Double traction power supply mode

The voltage of the urban light rail supply network is usually DC 750 V or 1500 V, and the network voltage of the urban trunk railway is usually AC 25 kV, which requires the vehicle to be equipped with a transformer, as shown in Figure 3.

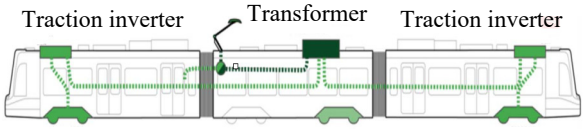


Fig. 3. Double traction power supply diagram

2.6. Keep the characteristics of convenience and high safety of low-floor trams

This requires that the vehicle can pass through the city's small radius curve line, and the transfer rate of the door, the height of the car body floor, the traction and braking performance are consistent with the urban low floor tram.

2.7. Possessing the characteristics of urban trunk vehicles

Due to the low entrance height of urban low-floor trams, passengers can get on and off easily, and can pass quickly through small radius curves. This requires light rail trains to have luggage racks and bicycle parking areas, while the lower limit of the vehicle is high and the vehicle collision level is high.

3. Present situation in China

At present, China's major cities are in full swing to carry out the construction of urban low-floor tram projects, and major OEMs have not yet incorporated rapid LRV into the scope of research and development. Even if individual cities such as Harbin and Jinan have demand for rapid LRV, the project has been put on hold due to the lack of related vehicle products.

4. Present situation in other countries

In recent years, the modern light rail transport system in Europe has been significantly developed. Based on the introduction of overseas technology, Japan 's LRV promotes the localization process. After several years of development, it has been put into operation in several cities. Modern LRV is a tram with excellent performance. In recent years, low-floor trams have emerged to facilitate passengers. LRV has introduced the latest modern technology in vehicle design, line structure and control. Great progress has been made in environmental protection such as no exhaust emission, noise reduction, vibration reduction and comfort improvement. The marshalling and operation of trains can be diversified, and the freedom of distance selection between stations is large.The foreign rapid LRV has experienced nearly 30 years of development, and the products of the major

OEMs have also been upgraded many times [9-12]. The speed of the rapid LRV is basically between 80 km/h and 100 km/h, and the low floor rate is gradually transitioned from 70 % to 100 %, as shown in table 1 below.

Table 1. Statistics of rapid LRV types in foreign OEMs

Manufacturer name	Vehicle name	Operating time	Highest speed	Low floor rate
Alstom	Regio-Citadis	2007	100 km/h	75 %
	Citadis dualis	2011	100 km/h	100 %
	Citadis spirit	2019	105 km/h	100 %
CAF	Urbos AXL	2015	90 km/h	80 %
Stadler	Citylink	2006	100 km/h	70 %
	Tango AARHUS	2017	100 km/h	100 %
Siemens	S70	2006	100 km/h	80 %
Bombardier	Flexity swift	1995	100 km/h	70 %
	Flexity E-lcass	2013	80 km/h	100 %

Comparing the latest tram-train vehicle technical parameters of Alstom, Stalder and Bombadier, it is found that:

1) The doorway height of the vehicle is basically the same as that of the low-floor tram;

2) The bogie can be rotated relative to the car body, and both of them are two-stage suspension;

3) Low floor rate 100 %;

4) The width of the aisle above the bogie is greater than 450mm;

5) In-car slope ≤ 8 %;

The specific parameters are shown in Table 2.

Table 2. Comparison of technical parameters of latest tram-train vehicles abroad

Management items	Alstom spirit	Stadler tango AARHUS	Bombadier E-class
Online operation time	2019	2017	2013
Maximum running speed	105km/h	100km/h	80km/h
Composition	4 car body 5 bogies (Figure 4)	3 car body 4 bogies (Figure 5)	3 car body 4 bogies (similar to Figure 5)
Vehicle length	48.5m	40m	33.5m
Axial column	Bo'2'Bo'2'Bo	Bo'2'2'Bo	Bo'2'Bo'Bo
Low floor rate	100%	100%	100%
Floor height	Door: 355mm Low floor area: - Above the bogie: -	Door: 350 Low floor area: 390mm	——
The narrowest Aisle width	610-640 mm	500-530 mm	470-490 mm
Transfer rate	>20%	>11%	16%
Maximum slope	⩽8%	⩽8%	Estimated ⩽ 8 %
Collision grade	CⅢ	CⅢ	——
ELE empty car weight	78t	50t	46t
Carrier (6 people/ m^2)	435	345	294
8 person/ m^2 axle load	<13t	——	<12.5t
Minimum curve radius	25 m	25 m	25 m
Bogie form	rotatable	rotatable	rotatable
Wheel set form	bending shaft +transmission shaft	rigid wheel set	rigid wheel set
Wheel diameter	640/570 mm	650/590 mm	——
Secondary suspension	air spring	air spring	hourglass spring
Primary suspension	steel spring	herringbone spring	rubber pile
Motor rated power	150 kW	135 kW	85 kW

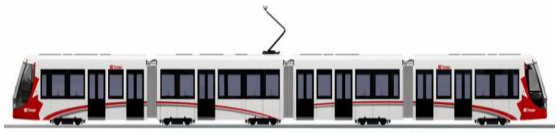


Fig. 4. 4 car body 5 bogie grouping

Fig. 5. 3 car body 4 bogie grouping

5. Suggestions

Based on the technical characteristics and development trend of rapid LRV in the world, it is suggested that the following aspects should be considered at least in the selection of China's rapid LRV schemes in the future:

1) Weighing the economy of operation and the maturity of vehicle technology, it is more reasonable to set the speed of rapid LRV between 80 km/h-100 km/h.

2) The technology of 100 % low floor rapid LRV is complex and the maintenance cost is high. The low floor rate of the rapid LRV developed in the future should not be less than 70 %.

3) In order to meet the higher number of passengers and vehicle comfort and motion stability requirements, when the vehicle length is less than 30 meters, according to the 3 module 3 bogie marshalling design; when the length is between 30 meters and 40 meters, it is designed according to the 3 module 4 bogie grouping; when the length is between 40 meters and 50 meters, it is designed according to the 4 module 5 bogie.

4) In order to meet the requirements of the carrying capacity of the urban low floor light rail line, the maximum design axle load of the bogie shall not exceed 12.5 t.

5) Referring to TCRP155, the tread shape matching the inner distance of the wheel back of the urban groove rail and the urban trunk railway is designed.

6) In order to reduce the wheel-rail wear and improve the service life of the wheel, the wheelset bogie which can rotate relative to the car body is adopted.

7) In order to share the platform with the low-floor light rail in the city, the floor height at the entrance of the car body should not be greater than 400 mm.

8) In order to meet the safety of walking and standing comfort of passengers in the vehicle, there should be no lateral steps in the interior area of the vehicle between the passenger compartment doors at both ends of the vehicle, and the longitudinal and lateral slopes of the vehicle should be set below 10 %.

9) The transfer rate of vehicles is consistent with that of low-floor trams, not less than 15 %.

10) The fixed seats in the vehicle shall not be less than 15 % of the number of seats, and all seats (including folding seats) shall not be less than 20 % of the number of seats.

11) Reserve the area for longitudinal parking of wheelchairs and bicycles.

12) The lower limit of the vehicle meets the requirements of the lower limit of the trunk railway, at least 80 mm.

13) Considering the existence of level crossings on suburban or suburban lines, it is recommended that the collision level of a single group of vehicles should be performed according to EN15227 CIII level.

Subject to the lack of related vehicle products, China's rapid LRV construction project has not been included in the scope of research and development, and other countries' products have been updated for many times under the development of more than 30 years. At present, rapid LRV in China has a certain gap with the international level in technology and coverage. In a sense, light rail transportation has become a symbol of developed urban transportation. Now we should change our ideas, learn from the advanced experience of other countries, realize the localization of high-tech equipment, and further improve the China's LRV into an economical, technologically mature, safe and comfortable transportation vehicle.

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