Construction of Shanghai Transrapid Demonstration Line

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Keywords
Transrapid, Shanghai demonstration line, High-speed maglev, Hybrid-girder, Guideway

Abstract
While selecting a most appropriate mode of high-speed ground mass transportation system for the nation, the Chinese government decided to build a high-speed maglev demonstration line in Shanghai after continual studies, with the purpose of acquiring detailed comparison data in respect of system technologies, safety concerns and economic assessments.

This paper is to introduce the first-ever commercialized high-speed maglev line, its construction progress and some key technical issues. The emphasis is on the technical improvements that the Shanghai Maglev Transportation Development Co., Ltd. (hereinafter referred as 'SMTDC') had made on the basis of the TR Guideway technologies from Germany and with the considerations of the reality of China. This paper ends with discussions on the development prospect of the high-speed maglev transportation technologies.

1 Introduction

High-speed maglev transportation system is a new type of track-bound transportation system. Equipped with the technical feature of non-contact operation by electromagnetic force, it is regarded as the only large-capacity ground passenger transportation tool in the world that can operate at a speed of 400-500 km/h safely and economically, and possesses a number of non-substitutable advantages.

China's large territory and population base have created a huge potential market for medium- and long-distance passenger transportation, ranging from 800km to 1500km. Parallel with the continuous and speedy economic growth and social development, the demand for high-speed passenger transportation in the nation has been growing rapidly. As a competitive large-capacity, high-speed transportation system available nowadays, the high-speed maglev transportation system is one of the imperative plans to be reviewed and considered in the selection of the nation's large-capacity passenger transportation system.

In 1999, there was a series of argumentations over the pre-feasibility study of the Beijing-Shanghai high-speed railway. Several experts, headed by Mr. Yan Luguang, an Academician of the China Engineering Academy, proposed for the State to adopt high-speed maglev technology on the Beijing-Shanghai rail line, bearing in mind with certain advantages of the technology, such as non-contact operation, high speed, quick acceleration, low energy consumption as well as minimal environmental consequences, etc. It's also been brought up that the Transrapid in TVE in Germany had been in operations for more than ten years with an accumulated mileage of over 600,000 km and the maglev transportation technology would shortly to be announced maturity by the German government. However, the proposal received tough resistance from other experts within the industry. They argued that technology of high-speed wheel-on-rail system had already fully matured after dozens of years' practices and China had also achieved tremendous progress in the development of this technology. Even though maglev system might have many advantages, due to lack of commercial applications, its technology, safety and economics needed to be further proved.

In the course of further technical argumentations, these two notions were locked in a stalemate. Later on, experts gradually attained a common understanding of constructing a commercially operated demonstrative maglev line at first to verify its availability, economics and safety. After comparing among several workable plans, in June of 2000 the government finally decided to construct the demonstration line project in Shanghai.

2 Overview of Shanghai Demonstration Line Project

Under the guidance and promotion of the Shanghai Municipal Government, Shanghai Shentong (Group) Co., Ltd., along with five other companies, made the commitment and invested to set up SMTDC. They at mean time decided to implement the construction and operations of the Shanghai Demonstration Line Project in a way of completely enterprise operations.

In November of year 2000, SMTDC and the German Consortium (consisting of Siemens AG, Thyssenkrupp Transrapid Systems GmbH and Transrapid International GmbH & Co KG) jointly finished the feasibility study report on the project. Both parties then immediately entered into the negotiations over the contract for equipment supplies and services. In January of the following year, such contract was officially signed. And the construction of the project kicked off formally in March of year 2001.

The Shanghai Demonstration Line project in general can be divided into 4 parts: vehicles, operation control, propulsion & power supply, and guideway & civil engineering. Among them, the guideway & civil engineering works were taken charge of by the Chinese partner. All the guideway design, constructions and equipment installations were to be performed by domestic Chinese engineers. Vehicles, operation control system, propulsion & power supply system, stator packs and motor winding cables attached to the guideway girders were supplied by the German Consortium thoroughly in together with technical supporting services.

The Shanghai Demonstration Line begins from Longyang Road Station of the Metro Line No. 2 in the west and ends at Pudong International Airport in the east. It is equipped with a main line of 30 km in length, double tracks, two stations, two propulsion substations, one operation control center and one maintenance center. Initially upon its completion, three vehicles with fifteen sections of each will be running on the track at a maximum speed of 430 km per hour, taking about 8 minutes for a one-way trip and 10 minutes' headway. It has been planned to start the test run at the beginning of 2003, while the deadline of finalizing the whole line is set for by the end of 2003. (See Fig. 1)

Fig. 1 Overview of Shanghai Transrapid Demonstration Line

3 Progress of Shanghai Demonstration Line Project

On the whole, the project is progressing smoothly in accordance with main milestones of the schedule. In February 2002, all design works were completed. Civil works on stations, maintenance center, propulsion substations and substructure of guideway were also basically concluded. The guideway girder manufacture base, specially built for the project, has attained its production capacity and is producing guideway girders ordinarily.

The works in 2002 are mainly the erection of guideway girders on the main line, installation of system equipment (which has already began in February 2002), and equipment commissioning. It is scheduled to re-assemble the first vehicle on site in this September, to finish the erection of guideway girders in the following month, and to start comprehensive commissioning of system equipment in the 4th quarter, hence to realize the test-run of the first vehicle with 3 sections early next year.

4 Technical Problems Solved in the Construction of Shanghai Demonstration Line Project

Guideway girders of the Transrapid system are the carriers of stator packs of linear motor. It has brought extremely high requirement in millimeter tolerance to the guideway girders. Since the changes of directions that definitely occur in any route alignment will result in problems such as horizontal and vertical curves, transition curves and cants between the inner and outer sides; many complicated twisted girders therefore have to be fabricated. The Shanghai Demonstration Line is located on the soft earth of river mouth deposit belt and the thickness of deposit is between 40-60m. In addition, the deformation of girder caused by temperature difference and dynamic load has to be treated. All these factors in combination have put forward very complicated technical requirements on the design and fabrication works of the guideway girders as well as load-carrying substructures. The hybrid girder technology introduced from Germany via technology transfer is not fully matured and lacks experiences in large-scale construction. Such technical difficulties once troubled SMTDC at the beginning of the construction. However, through intensive research by domestic experts and engineers, they were finally resolved and the smooth progress of the project had then been ensured.

4.1 Optimization of the Hybrid Girder Technology

The double-span hybrid girders is adopted in Germany to reduce deformation resulted from temperature difference and dynamic load and to satisfy the rigid requirements on the guideway system. Nevertheless, such kind of girder doubles the length of the girder and thus its weight will exceed 350 tons. Meanwhile, three supporting points of the double-span continuous girder can easily cause damages of the girder in the process of transportation and erection. Many difficulties will to be counted during manufacturing, processing, transporting, installing and positioning of the girders. Consequentially, it will also considerably increase the total cost of fabrication and erection.

The side reaction force against earth caused by temperature difference in horizontal direction of double-span girder also gives rise to a lot of difficulties to the design of substructures on soft land. After serious studies and experiments, a new concept of 'simple supported – continuous girder' special structure was eventually developed to solve these problems and got employed. At the same time, the scheme of changing post-tensioned cables was abandoned under the condition of keeping the original design concept. This approach has resulted in substantial efficiencies as well cost savings.

4.2 Development of Guideway Girders Across Small and Medium Rivers

As there is no girder across rivers at TVE Emsland, There is no design experience enough in this respect before. Yet, the Shanghai Demonstration Line will be crossing the Chuanyang River and Pudong Channel, requiring a net span of 40-45 meters. An overlapping structure of concrete and steel is hence developed and deployed successfully.

4.3 Development of Special Bearings for Guideway Girders

Because of the huge self-weight of the guideway structures, the load-carrying substructures built on soft land will inevitably lead to certain descending. As for Transrapid system, displacement of the guideway's upper-structures caused by the uneven descending of two adjacent columns must be restricted. A series of 3-dimensional, continuously adjustable bearings are therefore developed to make it possible to build tracks of high precision such as the guideway on soft lands.

4.4 Processing Machine for Hybrid Girders

The special 5-axis NC boring and milling machine for processing brackets of hybrid guideway girders is a key item to guarantee the accuracy of the installation of functional modules on the girders. The stroke of the machine tool carriage reaches 31 meters long and must follow the actual space position of the girder to adjust its own processing path. Furthermore, according to the requirement of the overall project schedule, these machine tools had to be developed, installed and put into operation within six months. Under joint efforts from several parties, the design, manufacturing, installation and commissioning of all eight special NC boring and milling machines were successfully completed by the schedule. They have been operating in good conditions up to the present.

5 Prospect of High-Speed Maglev Transportation System

Compared with other existing high-speed rail transit systems in the world, e.g. TGV in France, ICE in Germany, Shinkansen in Japan, one can find out a common characteristic of these

operation modes: they all will reach the destinations in less than 3 hours. It is a very important conception.
Research data indicate that traveling within 3 hours will not make travelers feel tired.
To cover the distance between two municipal centers within 3 hours makes it possible for people to complete business activities in a different city and return home on the same day.
A ground transportation system enabling passengers to reach the destination within 3 hours is good enough to compete against airlines, as air travelers are usually delayed by check-in procedures and security inspections, etc.

Unlike countries such as France, Germany or Japan, China has a vast territory while distances between provincial capitals normally exceeding over 1000 km. It is very difficult for wheel-on-rail trains with average speed of 300km per hour to attain the goal of covering the distance within 3 hours. Under such circumstances, high-speed maglev transportation system with average speed of 400-500 km per hour becomes quite attractive. While China being a developing country with a very large population base and a tremendous transportation demand, the economic capabilities of its people are still well below that of average people from developed countries. High-speed maglev lines may first be built in regions enjoying higher GDP.

Another possible application of the high-speed maglev transportation system is in rings of metropolises such as the Yangtze River Delta Region, which includes Shanghai, Suzhou, Wuxi and Nanjing; the Zhujiang Delta Region, including Hong Kong, Shenzhen and Guangzhou; and the Beijing-Tianjing-Tanggu Region. All these areas are relatively developed zones in China. If large and medium cities in these regions can be linked by high-speed maglev transportation systems, it is possible to attain the goal of arriving at a destination in half an hour. Thus large cities are quickly connected with surrounding cities, medium and small, and infrastructures such as airports, financial and trading centers, cultural and entertainment facilities as well as tourism resources can then be shared and fully integrated. As a result, resources will be allocated more reasonably and efficiently to remarkably push forward regional economic developments. . This is also a mode of priority development worth of considerations.

6 Conclusion

The successful construction and operation of the Shanghai Transrapid Demonstration Line will prove, for the first time ever, the safety, reliability and economics, as well as environmental compatibility of the high-speed maglev transportation system under fully commercially operational conditions. It will fully display the maturity of this technology and its commercial application values, and will play the unique role in system optimization and accumulation of experiences in operations and maintenances. This will be a turning point on the way from technical development of this technology to its maturity of application.

During the course of construction of the Shanghai Transrapid Demonstration Line, both of the Chinese side and the German counterpart have confronted quite a lot of difficulties. However, up to the present, major technical obstacles have been eliminated. The goal of starting test run at the beginning of 2003 and starting commercial operation at the end of 2003 could be then realized.