Development of the Maglev Transportation in China

Yan Luguang
Institute of Electrical Engineering
Chinese Academy of Sciences, 100080 Beijing, China
Tel: +8610-62553222, Fax: +8610-62529814
E-mail: lgyan@mail.iee.ac.cn

Keywords

Maglev in China, Shanghai Line, Beijing – Shanghai Line, Intercity and Urban Application

Abstract

The history of the passenger transportation of the whole mankind is a history of continuous increase of the operational speed. A very important achievement in this area for the 20th century is the appearance of the maglev train. China began the researches on key technologies of maglev train in the later 80's of the 20th century. The development and application of high-speed maglev train is promoted actively since the middle 90'. Significant achievements have been made in recent years. A certain common understanding has been reached that China needs the high-speed maglev train. The maglev demonstration and operation line in Pudong Shanghai has been built successfully with the cooperation between China and Germany. The plan for the next step is under active discussion and preparation. The present paper summarized China's progress in the development of high-speed maglev train and made some related suggestions for the development of maglev transportation in the near future in China.

I Introduction

The history of the passenger transportation of the whole mankind is a history of continuous increase of the operational speed. A very important achievement in this area for the 20th century is the appearance of the high-speed maglev train. Its development proved that the ground passenger transportation of mankind would reach 500 km/h level in the first part and middle of the 21st century.

China began the research of key maglev technology from the late 80's and the development of maglev train is actively promoted since the middle of 90's. Based on China's actual conditions and by analyzing and studying the international development experience and future prospects, it is suggested that our development strategy should consist of 5 stages: (1) studying of the necessity of the developing the maglev train in China; (2) construction of a operation line on the basis of importing foreign technology; (3) feasibility studying for adopting the maglev technology on long lines such as Beijing-Shanghai Line; (4) construction of long lines and realization of the industrialization and local production of the relative equipment; (5) application of the maglev train to play a important function step by step in China's future passenger transport network. In recent years, we have made considerable achievements. A certain common understanding has been reached that China needs the high-speed maglev train. A 30 km long maglev demonstration and operation line linking the airport with the city has been built in Pudong Shanghai by importing the German Transrapid system. The high-speed maglev technology has been included into the National High-tech Research and Development Plan

(863 Program) as a special technology [1~6]. The present paper describes in brief the major progress already made in our country, discusses the near future work in two directions, (1) to promote Beijing-Shanghai Line to adopt the high-speed maglev system by means of scientific comparison and selection. (2) to promote the possible application of maglev in the intercity and urban transport system.

II Construction and Operation of Shanghai Maglev Demonstration Line –Good Foundation for Future Development.

In view of the fact that the high-speed maglev train has been developed in Germany and Japan to be capable of build a line for practical operation and China itself is weak in research and development foundation and technical ranks, to promote the development of our maglev technology and industry, the first step is to import technology and build a demonstration and operation line. In 2000, China decided to construct the 30 km long maglev demonstration and operation line in Pudong, Shanghai, linking Pudong International Airport with the city. The construction started since March 1, 2001. After 22 months', the line was put into adjustment operation on December 31, 2002 and reached the design speed of 430 km/h. (Fig.1). From the beginning of 2003 till May of 2004, the maglev train has traveled about 770 thousand kilometers and carried about 790 thousand passengers. All adjustment and test work has been conducted successfully without any safety and accurate operation problems. The acceptance is already approved and the system started normal commercial operation since May 2004.

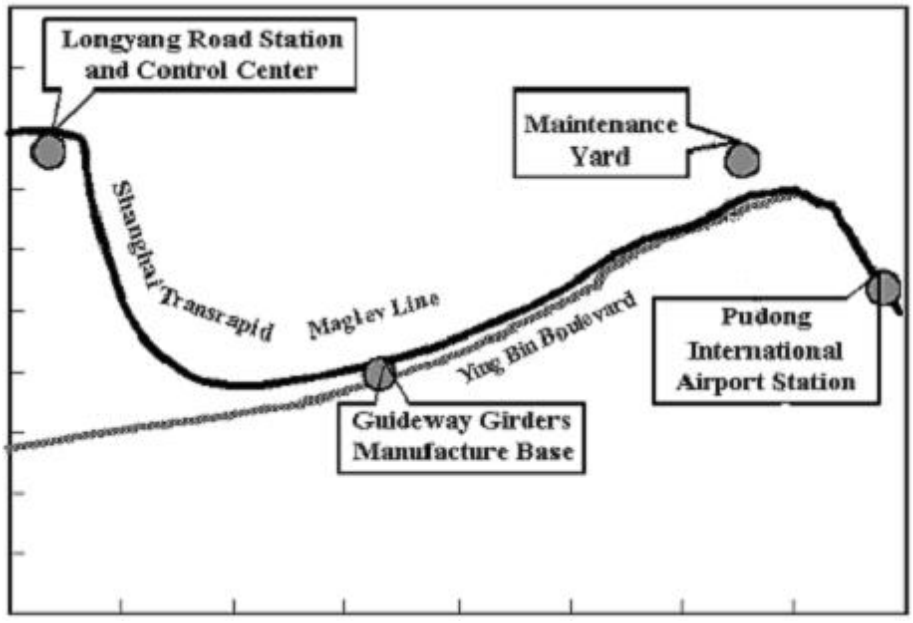

Fig.1 Scheme of the Shanghai demonstration line

The successful construction and operation of the Shanghai line solved many important problems concerning the practical use of maglev transportation system. It has created a solid foundation for further development in China, mainly:

(1) It has proved that the high-speed maglev is the only ground passenger transportation means for mankind to travel with a speed of over 400 km/h; the technology is mature and can be put into practical application and has good safety and reliability. Several hundred thousands of people took a

ride of the maglev train in the past months. The annual passenger transport volume may exceed 10 million people during normal operation. The people will have chances to experience by themselves the advantages of high- speed maglev train: a) low noise and low vibration; b) low resistance and low energy consumption; c) quick start-up and strong slope climbing ability; d) low maintenance.

(2) The test base for research and development of maglev system has been built in China. The 30 km long Shanghai Maglev Line allows a test speed to 500 km/h, making our country the 3rd one after Germany and Japan to possess such test capability. It will provide the important testing conditions and facilities to continue develop the maglev technology, improve the related equipment and manufacture new types of vehicles and become an important research and development base for Beijing-Shanghai maglev line and other applications. Of course, to make the Shanghai line as a test base needs further planning and more input for research and development.

(3) The ranks for the engineering construction, research and manufacture were greatly reinforced. In the design and construction of Shanghai Line, we have organized our own ranks of research and design, engineering construction, installation, commissioning and operation. Based on the imported technology, the construction ranks have well developed the guideway girder manufacturing technology, undertook all the civil engineering work and satisfied the set requirements. Although the vehicles, measuring and control system and electrical equipment are manufactured and provided by Germany, now our engineers can quite well understand them through training, installation and commissioning. Our people have mastered the application and operation technology. The research on local production is actively underway. We shall be the first to gain practical operation experience in the world. According to the preliminary analysis, the system design, guideway line, operation control, propulsion and power supply, operation and maintenance, safety and environment are all applicable to the long Line. So the Shanghai line has made active preparations for the long Line in science, technology, engineering and management.

(4) Very high construction speed was achieved. In 1999, we assumed that the construction of a test operation line would take 6–7 years, but the actual result is that it took 4 years from starting the feasibility study to putting into operation of the line at the end of 2003. The attained construction speed has won the appreciation of the world.

(5) The experience in cooperative development by China and Germany has been accumulated.

III Promotion to Adopt the Maglev Concept for Beijing–Shanghai High-Speed Line through Scientific Comparison and Selection

Fig.2 presents the scheme of the proposed Beijing-Shanghai high-speed railway, the total length is 1307km, operational velocity is 300-350 km/h, and the travel time from Beijing to Shanghai is about 6-7 hours.

Our railway people already worked more than ten years for the preliminary design and development of the Beijing-Shanghai high-speed railway and are waiting for the final government decision. The completion of Shanghai Maglev Demonstration and Operation Line has proved that the maglev concept is also feasible as one possible concept for Beijing-Shanghai line together with the high-speed railway, the central government leader asked to conduct scientific comparison and selection for finial decision to adopt high-speed maglev or railway for Beijing-Shanghai line.

The adoption of the maglev concept for Beijing-Shanghai Line is very important for the Line itself, for China's future high-speed passenger transportation network and to realize the industrialization and other applications, for the technical leap-over of the development and for the reasonable, coordinative and sustained development of our future passenger transportation.

Fig.2 Proposed Beijing-shanghai high-Speed railway scheme

(1) The high-speed maglev line of 500 km/h is mainly applicable to high-speed passenger transportation of long distance, big volume and between big cities. Long-term statistical data of Japan has shown, in the competition with civil aviation, the high-speed railway of 300 km/h can keep its advantageous status in the traveling range to 700 – 800 km. With the high-speed maglev of 500 km/h, it is estimated to keep its advantage in a traveling range to 1,500 – 2,000 km. Beijing-Shanghai Line is 1,300 km in length. According to the traveling time, high-speed railway is difficult to compete with the civil aviation, but the high-speed maglev train can cover the distance within 3 hours, which has a competitive potential.

(2) A high-speed passenger network of 8,000 km is to be built in the first half of 21st century in China (Fig.3). Since the distance between big cities is mostly more than 1,000 km, the adoption of high-speed maglev technology is beneficial to China with wide territory, big population and lacking of oil resource. A reasonable and coordinative arrangement of the future passenger transportation (including civil aviation and highway) and its continuous development to keep the important position of the rail transportation is of special importance. The adoption of maglev concept for Beijing-Shanghai Line will enable the maglev to be a leading technology of our future high-speed

passenger transportation network and will set a good example for the technical leap- over development of our country.

(3) Because Germany and Japan have made long-term efforts, the maglev technology in the world has matured to a degree that it can be used to construct a practical operation line. Practical application and industrialization are the main tasks at the present development. The difficulty in the past decade of years is that there was no suitable project. Beijing-Shanghai Line is a long line of first choice to implement the high-speed passenger transportation in China. It is also the only long line in the world to begin the construction at the first part of the 21st century. Its adoption of the maglev concept can bring the industrialization and to form the related high-tech industry of the whole system. China will play a major function in establishing a new and high-tech frontier industry.

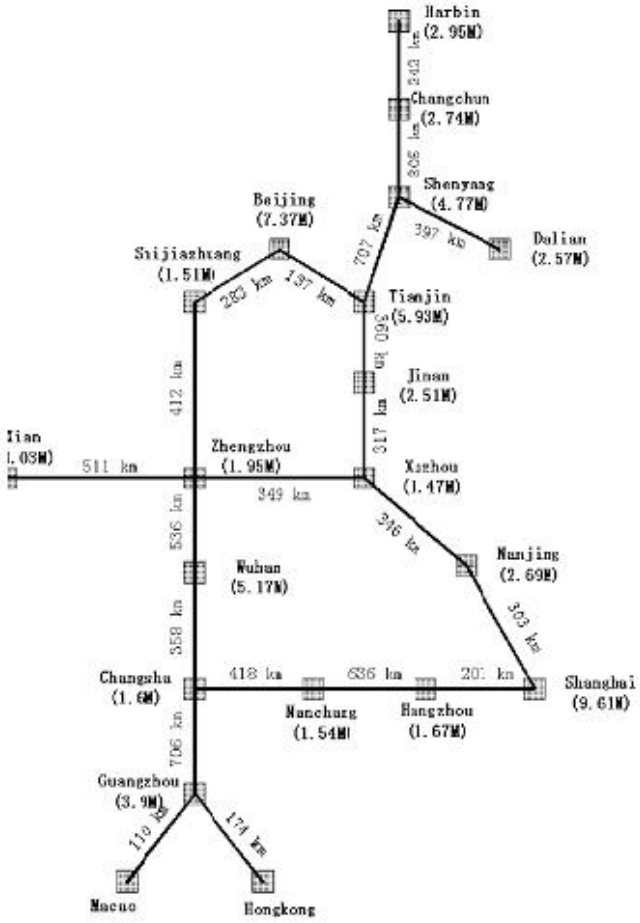

Fig.3 Schematic Diagram of the proposed High-Speed Network in China

In view of the successful completion of Shanghai Maglev Demonstration and Operation Line and the advantages of the adoption of maglev concept for the Beijing-Shanghai Line, we actively suggested to make a decision that Beijing-Shanghai Line should adopt the maglev concept and to make serious and overall arrangement for the work of the next step. However, as a major and important project of the world's attention after the Three-Gorge Project, there are still different opinions concerning the concept selection of Beijing-Shanghai Line. The Central government leaders

pointed out that it is important to “hear different opinions, make ample discussions, conduct scientific comparison and selection and present a plan”. It is very correct and we are in favor of it.

In order to carry out “scientific comparison and selection work”, some common understanding can be reached by means of hearing different opinions and having ample discussion, they are important basis for scientific comparison and selection, mainly:

(1) As for Beijing-Shanghai Line, both the high-speed railway transportation and maglev transportation are technically mature and feasible concepts. The high-speed railway is technically more mature, it is an advantage because it has more than 30 years’ operation experience in the world. We took 22 months to construct the world’s first maglev line for commercial operation and successfully reached the design speed of 430 km/h. It has solved some doubts existed before and proved that high-speed maglev is also a feasible, safe and technically matured concept that is applicable to Beijing-Shanghai Line. In the scientific comparison, the significance, advantages and reality of different concepts appear more and more important.

(2) Various transportation means have their own advantageous application areas. The advantageous travel distance of high-speed railway is within 800 km and while that of the high-speed maglev is to 1,500 – 2,000 km. The development of high-speed railway has generally proved its correctness. Up to now, 5 countries Japan, France, Germany, Italy and Spain have built 14 lines of a total length of 4,800 km. South Korea and Taiwan are building another 2 lines. Length of each project is less than 600 km. The territory of these countries or region is equal to a big province of China. Considering the advantageous application areas of these two technologies, high-speed maglev is mainly applied to high-speed passenger nation-wide network while high-speed railway is applied to main regional lines. Because the future transportation of our country has requirements in many areas, both technologies are needed in China. Reasonable, coordinative, scientific arrangements must be made according to the requirements and the respective advantageous application areas. The adoption of high-speed maglev for Beijing-Shanghai has obvious advantages.

(3) No matter what concept will be adopted, the construction of Beijing-Shanghai Line is an important project of international cooperation. Due to the enormous gap between China and the advanced countries in technical development, system engineering, industrialization and operation, as well as the increasing general-trend of international economic cooperation, we should go on the road of international cooperation if we want to build the Beijing-Shanghai Line as world advanced line quite quickly. In the world, Japan, Germany and France that have mastered such technologies have a high initiative for cooperation. The construction of Shanghai Maglev Demonstration and Operation Line under the cooperation of China and Germany has a good beginning. On such basis, the construction of Beijing-Shanghai Maglev Line will go with the continuous efforts of both countries. In the field of high-speed railway, we have close contacts and exchanges with many countries, but it is still facing the problem of selecting a cooperative partner and choosing the technical line. In the construction of high-speed railway by international cooperation, South Korea and Taiwan made their final decisions to cooperate respectively with France and Japan after a few years of fierce international competition. Such important international cooperative project like Beijing-Shanghai Line will be decided by considering many factors such as technology, economy and politics. It is important to promote competition and make comparison and selection in many aspects.

(4) The construction and operation of Beijing-Shanghai High-speed Line must promote the formation of local high-tech industries. Material and equipment used must be mainly produced in

China. Beijing-Shanghai High-speed Line with a total length of 1,300 km and having about 100 operation trains must be supported by a corresponding strong industries located in China. Together with the construction of Beijing-Shanghai High-speed Line, it is necessary simultaneously to make arrangement of technology transfer and the development of local high-tech industries. In view of the formation of new industries, the high-speed railway has formed a complete and strong industrial system in the world. The Chinese industry can only satisfy the needs of our own. The high-speed maglev has not formed an industry in the world. It is possible for our country to form a leading industry in the world. In addition to satisfying the domestic need, it is possible to occupy the international market. This is also an important reason why we are fighting to realize a technical leap-over.

(5) Comparison and selection of these two technical concepts must consider the strategy of coordinative and continuous development of our national high-speed passenger transportation. China's economy is at the stage of fast development. The entire country is working hard to achieve an overall well-off and the need for high-speed passenger transportation is ever increasing. The whole transportation system is under active development. We are in a key period to choose the future high-speed passenger transportation systems. The Government is planning it. High-speed railway and high-speed maglev must be chosen for the plan as a high technology. They should be developed in coordination with other transportation means and occupy their own advantageous positions. As a high-speed long line of priority, Beijing-Shanghai Line has a substantial influence on the development strategy of our future high-speed transportation.

In the discussions, there are some important different opinions. To solve them, it is necessary to arrange deeper and more detail work to achieve final scientific comparison and selection. The main problems are:

1) The construction cost. Recently, the discussion is more concentrated on the cost problem in the comparison and selection between the high-speed maglev and high-speed railway after solving the doubts of the maglev maturity and feasibility. The cost of Shanghai Maglev Demonstration and Operation Line is approximately RMB300 million/km. As to an operation line of several hundred km long, the project investment estimation shows that it can be decreased to below RMB200 million/km. As to Beijing-Shanghai Line of 1,300 km, its scale and industrialization will have a bigger effect on the decrease of investment. Even if the cost is relatively high in the initial period, it will be lowered in the later periods. It is possible to reach RMB150 – 170 million/km. The Ministry of Railways is still sticking to their estimate that the investment of high-speed railway is about RMB100 million/km.

For the comparison of economic benefits of the transport, we cannot consider only the construction cost and its depreciation. Maintenance cost, environment protection and operating fee should also be considered. The maintenance and operating fees of maglev train accounts for only a small share of that of high-speed railway.

2) The construction time. For many years, some people have held an opinion that the construction of Beijing-Shanghai Line is urgent and the earlier, the better. There are some different opinions. The key to the selection of the construction time lies in the correct estimation of passenger volume. One of the important reasons to stop the construction of Berlin-Hamburg Maglev Line in Germany is the over-estimate of the passenger transport volume. In 1998 when we discussed the construction of Beijing-Shanghai Line, there were some doubts mainly: a) the adoption of the design principle of mixed run of medium- and high-speed trains showed a shortage of high-speed passenger volume itself;

b) the actual passenger volumes since 1994 have a big difference from the estimated volume in the report. The estimated volumes show a rapid increase but the actual volumes from 1994-1998 were decreasing. The passenger volume rose to the level of 1993 from 1998 – 2001. In order to ensure the Beijing-Shanghai Line to be constructed on a fully-scientific and reliable basis, it is suggested that the forecast of the high-speed passenger transportation volume, construction time should be further studied and analyzed on the basis of the actual conditions of recent years.

3) The proposed construction plans. In order to make scientific comparison and selection, it is necessary to provide corresponding construction plans. For high-speed maglev, with the support of the National 863 Plan, some work has been done in aspects of applicability to long line and equipment local production. Some major design principles and the preliminary considerations for Beijing-Shanghai Line were studied; however, a lot of work has to be done before providing a comparable and selectable construction plan. In the field of high-speed railway, the Ministry of Railways handed over a project proposal in 1998 but it has not been further updated and improved according to the development in recent years. Some important issues are raised for the project proposal must be further studied such as the over-estimation of passenger volume, low estimation of investment, and if the principle of running both high and medium velocity passenger trains is suitable. As a construction plan, it did not touch the important issues of international cooperation and how to realize local production of equipment and materials. So the provision of a comparable and selectable construction plan also needs to do a lot of work.

4) About international cooperation and local production. As described above, international cooperation and local production are two important conditions to build Beijing-Shanghai Line into a modern advanced high-speed line. These two aspects have substantial influence on the comparison and selection, on the construction schedule and the quality. The related work is the important basis for scientific comparison and selection. Various types of co-operations and different plans are encouraged for competition. It is advantageous to compare and select the concept on the basis of the possible international cooperation and competition and lay a reliable foundation for future implementation.

To strengthen the scientific comparison and selection, it is suggested to conduct the following work in the near future:

a) To work out the high-speed railway and high-speed maglev construction plans for Beijing-Shanghai Line for scientific comparison and selection. A lot of preparation and predesign work must be done. It is suggested that the related work should be organized.

b) To build two short operation lines of 200-300 km long respectively for high-speed railway and for high-speed maglev, It will lay a reliable foundation for comparison and selection Based on the construction and realization of these practice operational line, scientific basis shall be obtained concerning the technical performances under different operating speeds, the construction cost required, the costs of operation and maintenance, international cooperation and local production etc. Historical experience has proved that the construction of Gezhouba Hydro-power Station in advance is of great significance to the construction of the Three-Gorge Hydro-power Station.

c) To include both high-speed maglev and high-speed railway into the national high-speed passenger transportation development strategy study. So they can develop coordinately in according with their own advantages.

Presently, the decision for Beijing-Shanghai line concept selection is delayed, the most important maglev work in the near future is to construct a 200-300 km operational line, for example, from

Shanghai to Hangzhou.

IV Application of Maglev for Intercity and Urban Transport System

Although the main advantages of the maglev is the high speed, it is the only one with the ground operational speed over 400 km/h, and the advantageous area of its application is the large passenger volume and long distance line, such as Beijing-Shanghai line. But the needs for such long lines in the world are quit limited; much more needs exist for the intercity and urban high-speed passenger transport system. For example, the three large megalopolis areas in China, the Yangtze River, Zhujiang and Beijing-Tianjin-Tangshan triangle areas are planning to develop their high-speed intercity and urban passenger transport very fast in the near future.

For the intercity and urban passenger transport, the low noise, low energy consumption and high acceleration rate advantages of the maglev also caused attention. Owing to these advantages, with the same distance between stations the maglev can run with higher velocity to shorten the travel time. The related work is under study in Germany and U.S.A., the successful construction and operation of the Shanghai line also created the foundation for application in this direction. Many people from areas, provinces and cities expressed their interest to consider the application of maglev for intercity and urban transport. So to form the future maglev transport system, we shall work simultaneously in two directions, i.e. for long line and for intercity and urban application.

Besides the transrapid system, for intercity and urban application, it is also possible to develop other systems; three of them are already under consideration in China, i.e. HSST type low-speed system (Fig. 4), High Tc superconducting system (Fig. 5) and the magneplane system (Fig. 6).

The work on HSST type low speed system with electromagnetic suspension and linear induction motor drive started in China at the beginning of 1980's by National University of Defense Technology in Changsha and Southwest Jiaotong University in Chengdu. Several test models have been developed. A 204 m long test line and a 15 m long, 3 m wide test vehicle CMS03 with 44 seats and 120 passengers for Badaling tourist line were constructed in 2001 (Fig. 4), up to now, over 16,000 test run were conducted with total travel distance of more than 5,500 km without any safety problem. A program to construct a 2 km tourist line at Badaling Great Wall in Beijing is waiting for approval. Similar work has been done also at Southwest Jiaotong University; a test line in Qinchenshan in Chengdu has been already constructed.

Fig. 4 HSST Type Low-Speed Vehicle CMS-03 Badaling
(developed by National University of Defense Technology)

Fig. 5 HTc Superconducting Test Vehicle
(developed by Southwest Jiaotong University)

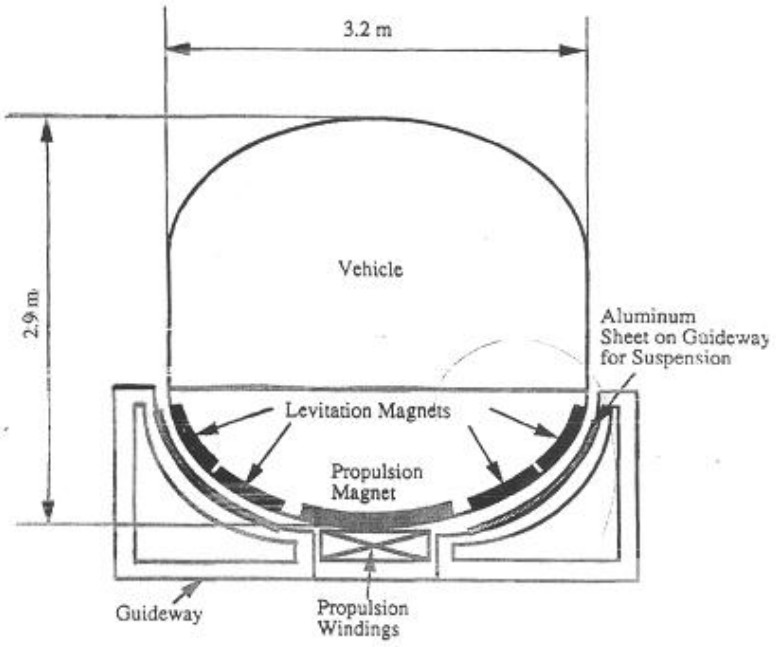

Fig. 6 The Cross Section Scheme of the Magneplane Vehicle

At the middle of 1990's study on high Tc superconducting maglev using repulsive force between YBCO bulk material and NdFeB permanent magnet for levitation started with Germany cooperation, a small test model was built at Institute of Electrical Engineering, Chinese Academy of Science to prove its principle, then under the support of the National High-Technology Development Program (863 Program) a test vehicle with 4 seats for demonstration was developed at Southwest Jiaotong University in 2000 (Fig. 5), the work is continuing.

The magneplane system (Fig. 6) proposed and developed under prof. Kolm and Montgomery in United States used permanent magnet and aluminum plate to form the electrodynamic suspension, it has some advantages in comparison with the existing systems. As a Sino-American cooperative program to develop this system in China is under active discussion, some work may be organized in the near future.

V Conclusion

China's maglev transportation has achieved remarkable progress with sustained efforts in recent years. A certain common understanding has been reached in that China needs the maglev train. The construction of Shanghai Maglev Demonstration and Operation Line has been completed successfully. It proved that high-speed maglev is a comparable and feasible concept together with the high-speed railway for Beijing-Shanghai Line. Due to the advantages and great significance of the maglev concept, we should continuous to do more work to let the Party Central Committee and the people to be confident to adopt of the high-speed maglev concept for the construction of Beijing-Shanghai Line. At the same time, we will also try to use the low noise and high acceleration advantages of the maglev transport to apply it for intercity and urban transport system.

The future of the maglev transport in China is quite bright!

3 References:

1. Yan Luguang. *Technology of the High-Speed Magnetic Suspension Vehicle and Its Strategic Position in China's Passenger Transport. Science and Technology Review*, No. 8, Aug. 1999.
2. Yan Luguang. *China Needs High-Speed Maglev Train*. Chinese Engineering Science, 2002, 2(5).
3. Yan Luguang, Xu Shangang, Sun Guangsheng, Dai Yinming, Zhang Ruihua, Wu Ying. *Strategic Progress of High-Speed Maglev Vehicle and the Development Strategy in China*. Advanced Technology of Electrical Engineering & Power, Vol. 21, No.4, Apr. 2002, Oct. 22, No.1, Jan. 2003.
4. Yan Luguang. *Considerations of the Development Strategy of China's High-Speed Maglev Vehicle*. Science and Technology Review, Volume 12, No. 4, Apr. 2002.
5. Yan Luguang. *Beijing-Shanghai Line Should Adopt the Maglev Concept. Science and Technology Review*, No.6, Jun. 2003. Advanced Technology of Electrical Engineering & Power, Vol. 22, No.3, July 2003.
6. Li Hong. *Conception for the Development of China's High-Speed Railway Passenger Transport*. Journal of Railway Engineering Society, Supplement, 1999, Collected Papers of the Symposium "Counter-Measures of Railway Construction Across the Century".
7. Yan Luguang, *Progress of High-Speed Maglev in China*. IEEE Trans. On Applied Superconductivity, Vol. 12, No. 1, March 2002.
8. Yan Luguang, *Suggestion for Selection of Maglev Option for Beijing-Shanghai High-Speed Line*. Paper presented at 18-the International Magnet Technology Conference (MT-18), Oct. 2003