Dynamic Analysis of High-Speed Railway Alignment

Theory and Practice

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高速铁路空间线形动力学分析理论与方法

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Introduction

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CHAPTER OUTLINE

High-speed railway technology mainly reflects the traction power, vehicle, route and track structure, communication signal, organization of train operation, operation management, etc,. in the progress of science and technology. Improving high-speed railway technology is the most effective way of greatly improving the railway capacity of passenger transport and service level.

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1.1 TARGET SPEED FOR HIGH-SPEED RAILWAY

Target speed for high-speed railway is the basis of layout and design for high-speed railway location, vehicles, research and manufacture of other equipment, market requirement prediction, economic benefit, and social benefit evaluation. Target speed for high-speed railway is the most basic parameter of developing high-speed railway systems.

1.1.1 THE PRINCIPLE OF DETERMINING TARGET SPEED FOR HIGH-SPEED RAILWAY

The driving speed of high-speed railway is the symbol of railway modernization. It is not only the basis of railway location design criteria and selection of equipment types but also the basis of vehicle selection and manufacturing. In addition, traveling speed is very closely related to the target speed, which is the basis of high-speed railway market analysis and economic evaluation.

The relationship of infrastructure top speed, mobile devices top speed, and commercial operation speed is as follows:

infrastructure top speed > mobile devices top speed > commercial operation speed

Commercial operation speed is the basis of researching target speed. To determine the commercial operation speed we need to consider the development of the social and economic situation, analyze market requirement for high-speed railway traveling speed, base the technical features of high-speed railway, and determine the top speed of train operation.

Mobile devices top speed should retain some leeway on the basis of commercial operation speed to adapt to changes in the market demand for commercial operation speed requirements. Mobile devices top speed should be able to meet the target commercial operation during the life of the speed of the mobile device requirements.

Infrastructure is high-speed train running carrier. It requires huge investment and has long service life. Once the infrastructure is completed, reconstruction is difficult. There should be long-term study of social development and forecasting of mobile devices top speed of long-term requirement to ensure that infrastructure can adapt to long-term social and economic development.

In general, with the higher target speed for high-speed railway, infrastructure construction costs are more expensive. At the same time, the development cycle of vehicles and related equipment are longer and manufacturing costs also are increased. To deal with the relationship among the three target speeds is the major technical and economic issue in high-speed transportation system planning. On the one hand, if the speed that is reserved from infrastructure design speed to the actual train speed is smaller, it will save initial investments in the construction of railway lines. However, if railway lines need further acceleration, infrastructure renovation project amount will be great and the speed increase will be not obvious. On the other hand, if the reserved speed is very large, it will require higher capital investment at low economic level stage. Meanwhile, it will increase the difficulty of financing projects and bring a heavy financial burden on the beginning of the operation.

In Japan, infrastructure design speed reserved room is small. Conventional railway uses lower technical standards, and the track structure is narrow-gauge railway. So now into the 20th century, the railway infrastructure cannot meet the market demand and technology development in terms of traffic speed. In particular, when high-speed railway needs develop, the government has to build a new gauge system called the standard gauge system. As a result, the situation of one country with two systems makes operation and management inconvenient. In the development of high-speed railway, Tōkaidō Shinkansen infrastructure target speed also used a lower civil engineering design standard so that there is no difference between infrastructure design speed and rolling stock's top speed. So with the upgrading of the train and the improvement of operating speed, the infrastructure cannot adapt gradually. Some problems have constrained further improvement in operational speed, such as mud pumping, tunnel aerodynamic influence, and noise.

Although the Europe's railway is the oldest, which was mostly built in the middle of the 19th century, the technical standard of its infrastructure left large gaps. Railway adapted to the development of social economy and technology in the long period so that it still plays an important role. For example, Germany's existing railways, whose design speed is 160 km/h; civil engineering; and other infrastructure facilities are still in use. With the development of the social economy and the tilting train technology maturity, line can achieved 200 km/h or higher driving speed, even with high-speed trains. Today, in the whole of Europe, although the high-speed passenger-dedicated lines are less than 3000 km, lines with high-speed trains are more than 10,000 km. It makes high-speed rail still outshine and achieve good economic results in the railway industry facing a downturn as a whole.

For these reasons, when planning our high-speed rail system the relationship among infrastructure design speed, mobile device design speed, and commercial operation speed must be handled. Generally, it should follow the following principles.

1.1.1.1 Comply With the Requirements of Macroeconomic Development

High-speed railway as a mode of transportation has its specific technical, economic, and social characteristics. It is large-scale construction, having an important influence on national transportation system structure, economic layout, energy, and environmental conditions. Thus high-speed railway target speed should help to improve the transportation system structure to meet the long-term national development plans and to comply with the country's political, economic, energy, and environmental policies.

1.1.1.2 Comply With China's National Conditions

The situation of China should be considered as the fundamental starting point to develop target speed. With economic development, the concept of time value is enhanced, incomes continue to improve, and the quality requirements for transportation services are also rising. Improving railway speed has become the objective requirement of people's travel, but it is limited to the level of economic development and the domestic technology. So it should take into account the technical and economic feasibility of high-speed railway construction project. Besides, the introduction of foreign equipment should consider the amount of the state's finances, the domestic development of equipment and processing levels of related industries in China.

1.1.1.3 To Market Demand, Taking into Account Long-Term Development

Market requirement is the basis of high-speed railway for its survival. It should study deeply the speed requirements of the railway transport market to maximize gain market share; studying potential demand for high-speed railway transport can lead to maximizing the number of additional passengers to ensure economic efficiency.

Because of the huge investments of high-speed railway and infrastructure with long life, related people should thoroughly analyze the long-term changes of transport demand and develop a reasonable mobile devices top speed and infrastructure top speed to meet medium- and long-term needs of the transport market.

1.1.1.4 Pay Attention to Economic Investment Projects

Target speed has a significant impact on the economic benefits of high-speed railway investment projects. First, we should study the relationship among the target speed and the project investment and transportation costs. Moreover, we need to analyze high-speed train fares. Second, we should study the influence of target speed on travel time and fares. Third, by market analysis, we should study the impact of passenger fares and travel speed on passenger needs to find the maximum profit point.

1.1.1.5 Consider Regional Differences

Our country has vast land, many kinds of natural conditions, and widely different levels of economic development. Under different natural conditions, the target speed has different influences on project investment and operating costs. Similarly, under different levels of economic development, passengers have different ideas on the quality of service requirements and fares of transport. Therefore countries with different natural conditions and levels of economic development have different commercial operation speed, so as to have a different target speed.

1.1.2 THE INFLUENCE FACTOR OF TARGET SPEED FOR HIGH-SPEED RAILWAYS

The study of target speed focuses on meeting the maximum requirements of transportation market. First, it is necessary to study the best commercial operating speed in each case, and then you should predict the development of the law of the best commercial operating speed. After this, you should determine the speed target value of the mobile device at short and long terms. According to the speed target value at short and long terms, the speed target value of base facility should be determined.

To study the optimum commercial operation speed, the following main researches should be done:

- the commercial operation speed of high-speed railway from the velocity structure of transportation system;
- the suitable speed range of the technical characteristics of high-speed railway system;
- effects of different travel distances on the optimal operating speed;
- effects of different levels of economic development on the optimum operating speed;
- effects of different terrain conditions on the optimal operating speed.

1.1.2.1 The Economy Speed of High-Speed Railway

The economy speed is the most profitable speed of high-speed railway. At the beginning of building high-speed railway, European countries have studied the economy speed. Studies have shown that increasing speed can save travel time. However, with the increase in maximum speed, the improvement of building standards, and more advanced technology and equipment, railway investment is bound to increase. At the same time, requirements of maintenance quality for trains line and vehicles will be improved. Also, because of the large amount of energy consumed for air resistance, operating costs and transportation costs will be increased.

It is generally agreed that the purpose of increasing train speed is that the competition capacity with other modes of transportation and railway revenue are increased by reducing the travel time. Of course, competition with other modes of transportation does not simply depend on the speed, but at least it can be said that in the competition those who have longer travel time will be at a distinct disadvantage.

According to the view of Dr. Brighton in Switzerland, under the condition of average speed of 600 km/h (wait, replacement, and other required formalities need 90 min) for aircraft and 80 km/h for car, with 30 min for railway waiting and transfer time, when at close range (300 km or less), if the average speed of railway cannot reach 100 km/h, it cannot compete with the car. When in the middle distance (500–600 km), if the average speed of railway cannot reach 250 km/h or more, it cannot compete with the aircraft.

Before and after the 1970s, western European countries had studied their own economic speed according to their specific circumstances. The economic speed is 230 km/h in Britain, 280–300 km/h in France, and 270 km/h in Germany. However, according to the result of the International Union of Railways, economic speed is 300–350 km/h. Economic speed can be a guidance for the maximum speed. In general, the maximum speed is slightly higher than the economic speed.

In May 1985, Economic Commission for Europe established a definition for railway running speed. It defined a maximum operating speed of 300 km/h for high-speed passenger special line, 250 km/h for mixed passenger and freight transport, and 160–200 km/h for existing railway reconstruction.

Practice in China has proved that 300–350 km/h speed should be economical and reasonable for long high-speed railway.

1.1.2.2 The Suitable Speed Range of Technical Characteristics of High-Speed Rail System

1.1.2.2.1 The Limit Speed of Adhesion Railway

With the interaction between wheel and track, normal railway will produce traction force. The maximum speed achieved in the normal railway is called the limit speed of adhesion railway. When the speed increases, the traction force gradually decreases and the running resistance gradually increases. When the traction force is equal to the running resistance, the speed cannot increase any more. This speed is called the limit speed.

According to earlier studies in Germany and France, the limit speed is considered as about 350 km/h.

In February 1981, in France, the TGV16 EMU reached a speed of 380 km/h and set a record.

In 1988, in Germany, the ICE reached a speed of 406 km/h and set a new record.

In 1986, France set a new speed record of 482.4 km/h again.

In May 2000, in France, the TGV325 reached a speed of 515.3 km/h and set the current world record. The French believed that the test speed was potential and could be increased. However, it was difficult to reach 500 km/h business speed, especially with the problems of line maintenance.

These facts show that, under the present conditions, on choosing economical and reasonable target speed values, the limit speed of adhesion railway will not be a limiting condition.

1.1.2.2.2 The Speed Determined by Traction Characteristics

Since the air resistance that the train suffers is proportional to the square of speed, when the speed of high-speed railway increases to 500 km/h, the air resistance that the train suffers is three times as big as that when the speed is 300 km/h. Relevant study shows that the dynamic performance of air resistance at this time is close to uneconomic state. Under high speed running, it should be taken into consideration when the train runs on thin air environment, namely, aspirator pressure tunnel or using aircraft flying at low altitude air density of the atmosphere. According to the traction characteristics of high-speed railway in China, for eight marshalling CRH3 EMU, when the maximum speed reaches 350 km/h on a flat ramp, its running resistance and traction reach balanced state (Fig. 1.1).

The running speed is also connected to the train mass. For example, when the train mass is 800 t, the top speed is stipulated as 250 km/h and the needed total power is 9600 kW. If you use the high-speed EMU whose single shaft power is 1100 kW, it will need nine movable shafts. If you use the EMU whose single shaft power is 1200 kW, it will need eight movable shafts. Also, if the power does not