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Preface

As the saying goes, "the height you stand decides your view, the points of view you observe changes your concept, and the measure you choose grasps a better life." While "speed" determines transportation, "transport capacity" changes the transport modes and the "technology" ensures the traffic safety. High-speed rail (HSR) is regarded as a vehicle that changes human life and characterized by "There is not a fastest vehicle, only faster." Compared with other transport modes, HSR has many advantages such as strong transportation capacity, high operation speed, high safety, high punctuality rate, low-energy consumption, little influence on the environment, land conservation, comfort, convenience, considerable economic and social benefits. With its unique technical advantages, HSR has adapted to the new demands for economic development of modern social. As a result, HSR has become an inevitable choice for the development of countries around the world. In particular, the development and operation of China's high-speed rail indicate that HSR has great development space and potential in China. China would better make full use of its latecomer advantage to realize the leap-forward development of HSR. Therefore, *A Brief History of High-Speed Rail* is a reading book that introduces the basic knowledge, concept terms and development history of HSR and sorts out the main results of HSR at this stage. This book mainly explains the connotation of HSR for readers from two different aspects of theories and technologies. Combining the characteristics of high-speed rail and the development trend of the world, this book introduces the development meaning of high-speed rail. The main contents are as follows:

(1) Concept term of HSR. Related terms of HSR, especially the definition of HSR and the speed classification, as well as the main attributes of HSR, such as speed, capacity, safety, comfort, economy, energy efficiency, environmental protection and so on.
(2) Development trend of HSR. Introducing the development trend, technological features and application prospect of the three classes of Wheel High-speed Rail (WHSR), Magnetic High-speed Rail (MHSR) and Super-speed Rail (SSR), those are the past, present and future of HSR development. This book is mainly about two aspects. On the one hand, the author describes the development of

HSR in time—yesterday, today and tomorrow. On the other hand, the author comparatively analyzes the development trend of HSR in domestic and foreign countries (especially the HSR comparative analysis of Japan, France, Germany and China) in space. Through the comparative analysis, readers can understand the development trend of China's HSR in the world, ranking first in terms of "quality" or ranking first in "quantity."

(3) Regional integration in the environment of HSR. Various types of HSR promote integration level among different regions. WHSR promotes the regional integration, MHSR promotes the continental integration, and SSR promotes the world's integration, leading to a global village. Therefore, we must pay attention to the development of HSR. At present, countries that master the core technology of WHSR, MHSR, SSR, etc., will own the world.

This book is created by the Qizhou Hu team of High-Speed Rail Science Research Institute. The team members mainly include Senior Engineer of Shanghai Railway Bureau Siyuan Qu, graduate students of the Nanjing University of Science and Technology Jie Chen, Ziquan Cong, Minjia Tan, Airan Zeng, Lishuang Bian, Xiaohan Li, Min Yue, Yikai Wu, Xin Guan, Song Ding, Longxin Zheng and Xiang Lin.

For a popular science book, benefiting the public is the highest aim. However, some of the pictures and contents of this book come from the Internet. Since we cannot find the source, we can only express our gratitude and respect here for them. We are also grateful for the selfless help from the editorial staff when we are in the writing of this book.

This book can be used as a reading material for researchers, engineers and technical personnel, management workers, college teachers and students and high-speed rail enthusiasts. Limited by time and knowledge of us, there are inevitable omissions and inadequacies in the book. Please enlighten us. Thank you.

Nanjing, China — Qizhou Hu
Shanghai, China — Siyuan Qu
August 2018 — The Writer

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Chapter 1
Introduction

With the official operation of the world's first High-speed Rail (HSR) in Japan on October 1, 1964, HSR opened a new era of transportation development. "There is not a fastest vehicle, but only faster vehicle", speed and capacity are eternal pursuit of mankind. No matter what kind of transportation (trains, cars, airplanes, ships, etc.), the requirements of human beings for it not only depend on speed but also on transport capacity.

Although the aircraft operates at a high speed, its transport capacity is limited. While the train has a large transport capacity, but it runs at a low speed. Therefore, the pace of human's pursuit of transport never ceased, and HSR is the crystallization of human wisdom in transportation. The French Wheel High-speed Rail TGV (train à grande vitesse, TGV) is as shown in Fig. 1.1.

HSR is an abbreviation for high-speed rail. It is a large system composed of dedicated lines, high-speed trains, and dedicated control systems. Therefore, HSR is a system concept but not an individual concept. The "high-speed" in the high-speed rail refers to the quality, while the "rail" is the property. In addition to Wheel High-speed Rail (WHSR), HSR also includes Magnetic High-speed Rail (MHSR) and Super-speed Rail (SSR). Therefore, the narrow concept of HSR refers to the WHSR transport system. The broad concept of HSR includes not only the WHSR transport system, but also the MHSR, which is using the magnetic levitation technology, and the SSR transport system in the vacuum track. Figure 1.2 is a diagram of high-speed rail train.

HSR has become a hot issue in the world. This is because HSR has some technological advantages that are incomparable to other modes of transportation. The first advantage is the high speed. The French WHSR TGV set a world record with the speed of 574.8 km/h. Japan's MHSR set a world record with the speed of 603 km/h. The America's SSR set a world record with the speed of 1000 km/h, and it faster than the normal speed of the airplane. The normal speed is 800 km/h. The second advantage is the large volume. The interval of HSR trains can be as short as 4 min and twelve trains can be operated per hour in one direction, which is incomparable to

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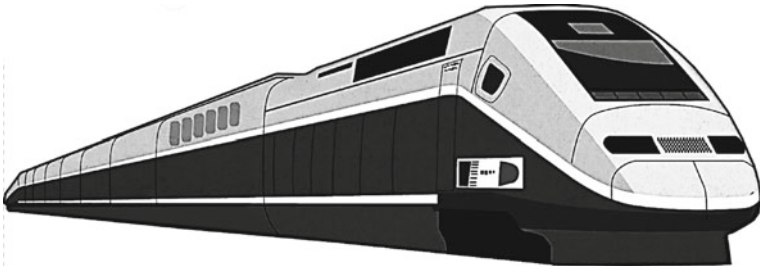


Fig. 1.1 French WHSR: TGV

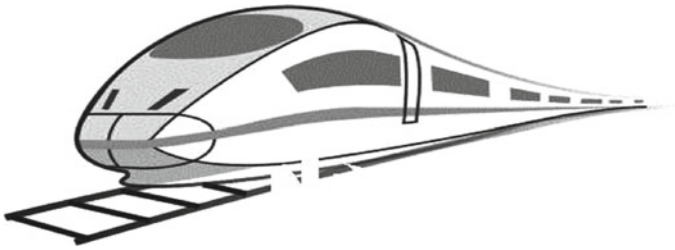


Fig. 1.2 HSR train

highways and aviation. The third advantage is the high safety. The quality and precision of HSR line facilities are high. The train operation control system uses mature electronic technology and intelligent software which ensures the safety distance between the two trains. Therefore, there are few accidents in HSR around the world. Fourthly, HSR can operate throughout the day because it cannot be affected by rain, snow, fog, wind. Fifthly, HSR also has the features of low energy consumption, land conservation, light pollution and high comfort. Therefore, HSR has been welcomed by most countries in the world since its birth.

1.1 Emerging Conditions of HSR

(1) The production of vehicle requires certain conditions. No matter which kind of transportation, human beings appraise it from three aspects. The vehicle that can meet these requirements is good, but not vice versa. First is the functionality such as speed, capacity, and safety. Second is the economics such as cost, energy, and efficiency. The final one is the ecology such as noise, radiation, and environmental protection. As a means of transportation, HSR also takes the load into account while pursuing high speed. Noting that high speed and heavy loads are the eternal pursuit of mankind, HSR exactly meets human needs. Figure 1.3 shows Wheel High-speed Rail system.

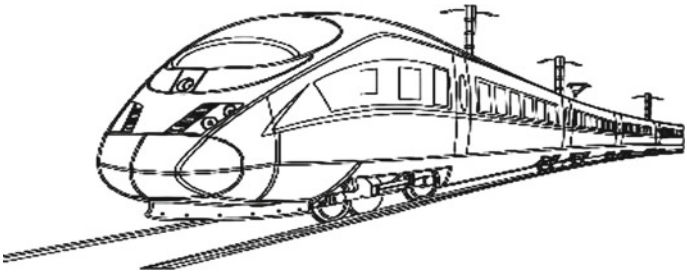


Fig. 1.3 WHSR system

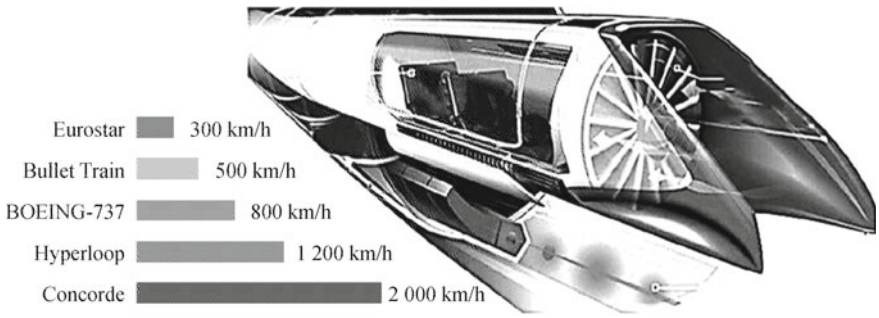
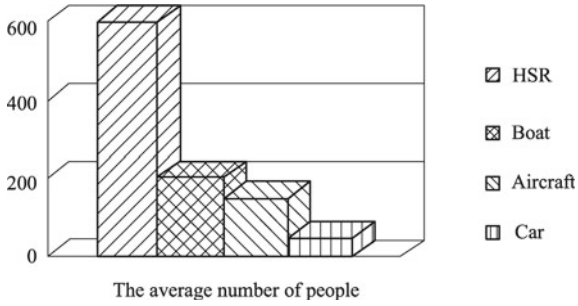


Fig. 1.4 The operating speed of different vehicles

(2) The speed of HSR. Speed is the basic requirement for transportation. It is exactly the rapidity and high efficiency that make the HSR popular with humans and developed greatly. A comparison of speed between HSR and other vehicles is shown in Fig. 1.4.

(3) The load of HSR. In order to meet the basic demand for transportation, people expect vehicles to carry as much weight as possible. The comparison of the loading capacity between HSR and existing vehicles (cars, airplanes, ships, traditional trains, etc.) is shown in Fig. 1.5, from which we can obtain that the HSR is the vehicle with the largest load.

Fig. 1.5 Comparison of the loading capacity between HSR and other vehicles



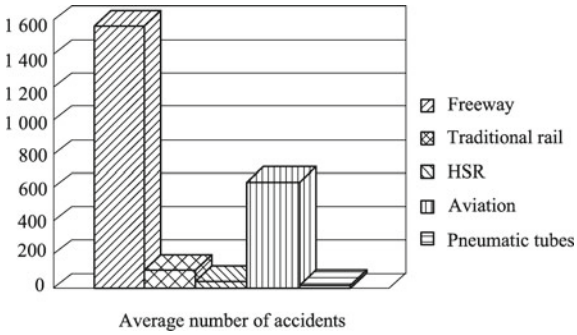


Fig. 1.6 Comparison of safety between HSR and other various vehicles

(4) The safety of HSR. Since HSR is operating automatically in a fully enclosed environment and has a series of comprehensive safety protection systems, its safety is unmatched by any other means of transportation. Several major HSR countries have to operate thousands of HSR trains every day. While the accident rate and casualty rate are far lower than other modern modes of transportation. Therefore, HSR is considered as the safest transportation. The comparison of safety between HSR and other various vehicles is shown in Fig. 1.6.

1.2 Three Leaps of HSR

In order to satisfy the demands for both speed and capacity, the HSR experienced three qualitative changes, namely three leaps. From WHSR to MHSR to SSR, from the operating speed of 200 to 500 to 1200 km/h, this is also the three leaps in human demand for transportation.

1.2.1 The First Leap: Improve the Speed of Operation and the Birth of WHSR

The first category: Wheel High-speed Rail (WHSR). To improve the speed of the train brings the first leap. So the first type of HSR, the WHSR was born. The traditional train and WHSR train are shown in Fig. 1.7.

In terms of capacity, the traditional train is the king of all modes of transportation. However, traditional trains usually run at a speed below 200 km/h, which cannot satisfy human's needs for fast travel. By strengthening the study of track and vehicle type, especially the improvement of vehicle type, people reduce the frictional resistance and air resistance of high-speed train running to increase the running speed. In Japan, the speed of HSR (Shinkansen) train reached 200 km/h in 1964. The train is called HSR when the operating speed is over 200 km/h. However, the WHSR can only operate between 200 km/h and 400 km/h due to air resistance and frictional

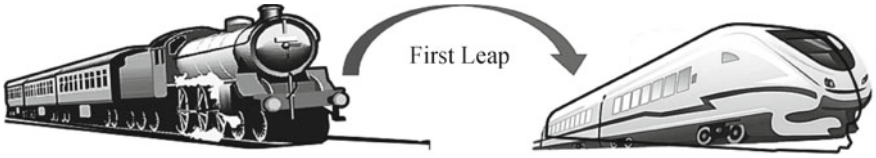


Fig. 1.7 Traditional train and WHSR train

resistance. The operating speed of 400 km/h is the warning threshold of WHSR. When the WHSR train exceed this speed, it is extremely easy to derail and cause traffic accidents. WHSR train is as shown in Fig. 1.8.

Wheel High-speed Rail is mainly a transportation system running on the track, which is generally shortened for WHSR and can also be called conventional HSR. The main features are as follows:

① The operating speed of the WHSR is about 200–400 km/h.
② The warning threshold of WHSR is 400 km/h.
③ The resistances of WHSR are frictional resistance and air resistance.

WHSR belongs to the wheel-rail type of HSR. According to the definition of the International Railway Union, HSR refers to the railway system that has an operating speed of more than 200 km/h by transforming the traditional line (straight line, gauge standardization), or has an operating speed of more than 250 km/h by building a new line. This book divides WHSR into three types. See Table 1.1 for details.

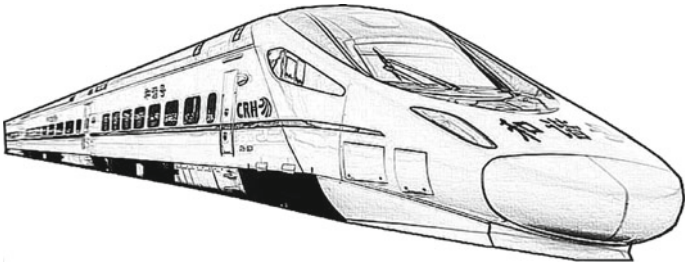


Fig. 1.8 WHSR train

Table 1.1 Types of WHSR

Number	Types	Speed/(km/h)	Name	Main countries	Remarks
1.	First	200–300	Low-speed WHSR	Japan, Germany	The warning threshold of WHSR is 400 km/h
2.	Second	300–350	Normal-speed WHSR	France, China	
3.	Third	350–400	High-speed WHSR	China	

1.2.2 The Second Leap: The Removal of Frictional Resistance Brings the Birth of MHSR

The second category: Magnetic High-speed Rail (MHSR). In order to reduce the friction between the wheels and the rails, the second leap was made. As a result, MHSR, the second type of HSR, was born. The WHSR and MHSR trains are as shown in Fig. 1.9.

In order to reduce the frictional resistance and improve the running speed and meet the fast travel requirements of human beings, MHSR was born with the running speed of more than 400 km/h based on the principle of "same-magnet repelling and opposite-magnet attraction". During the operation of the MHSR, the magnet train does not directly contact the track, but floats on the track so that there is no frictional resistance and then the running speed is improved. In 2015, the speed of MHSR in Japan has reached 600 km/h and more. Although MHSR is not affected by the frictional resistance, it can only operate at the speed of 400–1000 km/h due to the limitation of air resistance. The operating speed of 1000 km/h is the warning threshold of the MHSR. When this speed is exceeded, the operating cost will be too high. Among them, Japan's MHSR train is as shown in Fig. 1.10.

MHSR is the magnetic suspension type of HSR, which is mainly suspended on rails to run. It is also called superconducting high-speed rail. The main features are as follows:

① The operating speed of MHSR is from 400 km/h to 1000 km/h.
② The warning threshold of MHSR is 1000 km/h.
③ MHSR has air resistance but no frictional resistance.

Fig. 1.9 WHSR and MHSR trains

Fig. 1.10 Japan's MHSR train

Table 1.2 Types of MHSR

Number	Types	Speed/(km/h)	Name	Main countries	Remarks (0 K = −273.15 °C)
1.	First	400–600	Low-temperature MHSR	Japan, Germany	4.2 K—Liquid helium (rare, expensive)
2.	Second	600–800	Normal-temperature MHSR	Japan	15 K—Liquid helium (minor, reasonable)
3.	Third	800–1000	High-temperature MHSR	Japan	77 K—Liquid helium (much, cheap)

MHSR belongs to the magnetic suspension of HSR. As a new type of ground transportation, magnetic train has moved from the experimental stage to commercial operation and overcome the problems of traditional train such as the adhesion limit, mechanical noise and wear, etc. Besides that, MHSR has the features of high speed, strong climbing ability and low energy consumption, high noise, high safety, high comfort, no fuel, and little electromagnetic pollution. It has become the ideal vehicle for people.

The MHSR train can be divided into two types based on the principle of suspension: Electromagnetic Suspension (EMS) and Electrodynamic Suspension (EDS). The speed of MHSR train can reach 500 km/h, which is absolutely impossible for traditional train. If the superconducting magnet is installed in the train and an aluminum ring is laid on the ground track, the relative movement between them will generate an induced current in the aluminum ring. Then the magnetic repulsion will occur, lifting the train about 10 cm from the ground, allowing the train to float on the rail and operate at a high speed. This book divides the MHSR into three types as Table 1.2.

The MHSR train uses a superconducting magnet to float the vehicle and obtain propulsion power by periodically changing the direction of the magnetic pole. In addition to its high speed, the MHSR train has the characteristics of no noise, no vibration and energy saving. It is expected to become the main means of transportation in the twenty-first century.

1.2.3 The Third Leap: Reducing Air Resistance Brings the Birth of SSR

The third type of HSR: Super-speed Rail (SSR). When the train runs in vacuum, there is no limit to the operating speed. In order to reduce the air resistance, the third leap has been made. SSR, the third type of HSR, is the suspension of HSR in the vacuum pipeline. MHSR trains and SSR trains are as shown in Fig. 1.11.

Fig. 1.11 MHSR and SSR trains

The SSR was produced to satisfy human beings requirements for fast travel, based on the concept of vacuum pipeline by reducing air resistance. The SSR runs in the vacuum pipeline without air and frictional resistance, and the running speed can reach more than 1200 km/h. In fact, there is no air resistance and frictional resistance in vacuum pipeline, so the SSR train can operate "arbitrarily" and speed up to 10,000 km/h. The SSR system is as shown in Fig. 1.12.

SSR is a vacuum pipeline suspended HSR. It is mainly a HSR transportation system suspended in a vacuum pipeline. So SSR also can be called vacuum high-speed rail. The main features are as follows:

① The operation speed of SSR is 1200 km/h (acoustic velocity is 340 m/s).
② SSR has no limit of warning threshold due to no restrictions.
③ SSR has no friction resistance and no air resistance.

The SSR is a vacuum pipeline type of HSR. SSR is a kind of transportation system designed with the principle of "vacuum steel pipe transportation" as the core of the theory. It has the characteristics of ultra-speed, high safety, low energy consumption, low noise and low pollution. The super train may be a new generation of transportation

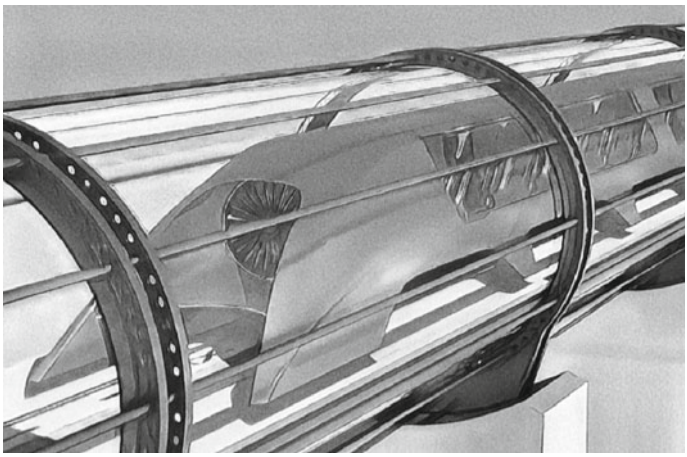


Fig. 1.12 SSR system