Advances in High-speed Rail Technology

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China's High-Speed Rail Technology

An International Perspective

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Foreword

The steam locomotive was first developed by Richard Trevithick in 1804, but several significant advances were made before its use on the Stockton and Darlington Railway in 1825, closely followed by the first true intercity railway in the world, between Liverpool and Manchester in 1830. George Stephenson and his son Robert were intimately associated with these early railways, so perhaps unsurprisingly, but not quite accurately, George Stephenson is known worldwide as the father of the railways. The railway rapidly became the most important mass transportation system because of its convenience, speed, efficiency, and considerable economic advantage over other existing but much slower modes. Although many improvements took place in the succeeding century, by the early 1960s, the railway generally was in decline in competition with, principally, the automobile. But in 1964, the opening of Japanese Tokaido Shinkansen marked the entry into the world of high-speed rail operating at high capacity and the rebirth of the railway. Modern high-speed rail technology assembles the world's advanced techniques in material science, control science, advanced manufacturing, electrical science and computing, which has made a big difference in safety, comfort, and speed compared with traditional railway technology, and has significantly changed people's travel habits and view of space and time.

The introduction of the railway to China was slow and tentative. A merchant called Durand from Britain built the 500 m of track in Beijing in 1865 as a demonstration. However, it was soon demolished by the Qing government as it was said to "have scared the dragon" and was not good for *Fengshui*. After several other abortive attempts, the first railway between Beijing and Jingzhang, about 200 km, was opened in 1909. However, even a century later in the early 2000s, there was still great gap between China and other developed countries in terms of per capita railway mileage and overall technical level of railways. Although a high share of goods and many people were transported by rail, capacity was a major constraint. For example, at times such as the Spring Festival, the railway supply can hardly match the enormous demand. To solve the problems, Chinese enterprises have set out to introduce high-speed rail technology from Japan, Germany, France, and Canada under the organization of the Ministry of Railways since 2004. And on the

basis of that, they have developed their own high-speed rail system of research, design, manufacture, construction, operation, and maintenance. In 2008, the Beijing-Tianjin intercity line opened. After that, Wuhan-Guangzhou, Beijing-Shanghai, and some other 350 km/h high-speed railway opened successively. Nowadays, both the scale and the speed indicators of China's high-speed rail have reached an advanced level in world. The new high-speed line length of 20,000 km now exceeds the total length of high-speed line in the rest of the world combined and is due to top 38,000 km by 2025. In total, China now has the second largest railway network in the world and the railway is firmly in place as the preferred mode of transport over longer distances in China. The achievements of the last 20 years or so have been phenomenal and deserve to be understood and appreciated by wide audiences throughout the world. It is my hope that this book will go some way to achieving this.

Professor Youtong Fang is an expert in the field of railway traction power, as well as my old friend in this industry. The permanent magnet traction motor he designed for the 350 km/h high-speed railway has been adopted, and the energy-saving effect is remarkable according to the test results of the line. At the same time, Prof. Fang participated in the organization of China's high-speed rail technology innovation. In 2010, Helen Zhang, the Chief Editor of Journal of Zhejiang University-SCIENCE A: Applied Physics & Engineering (JZUS-A), who has been concerned about the progress of high-speed rail technology in China, invited Prof. Fang as a guest editor, soliciting the first special issue about Chinese high-speed rail. Right during this period, the Yongwentai railway accident occurred on July 23, 2011, which caused various international comments about the high-speed rail technology of China. In December of the same year, under Prof. Fang' s organization, JZUS-A published the first special issue in English on China's high-speed railway technology, followed by another three special issues on high-speed rail of China, which aroused considerable interest throughout the world.

In 2014, Prof. Fang invited me to visit the China CSR, Qingdao Sifang, China Tonghao Group, Zhejiang University, and Beijing Jiaotong University. Also, we took the high-speed train from Hangzhou to Beijing. By sharing viewpoints with Chinese scholars, and from my perspective of studying railway for many years, I wrote an article called "Background of recent developments of passenger railways in China, the UK and other European countries," in which I commented that the high-speed train system has tremendous advantages in increasing the efficiency and convenience of transport without adding to carbon generation. It consists of a brief introduction to the history and comparisons of railways in the UK and China, a description of rail speedup in the last few decades in the UK, and notes of current high-speed trains. Similar brief details are given of high-speed train in Europe. Brief mention is made of comparative railway safety. The development of high-speed rail in China is discussed, and the UK high-speed development plan is briefly introduced. Later during Prof. Fang's visit to Britain, he talked to me about his plan, to publish a book which is a compilation of recent studies on high-speed rail technology in China from an international perspective, after getting the permission from JZUS-A and authors. And the book will contribute to the international

counterparts. He asked if I would like to write the preface for the book, and I readily agreed.

This book involves not only a comparison of railway development in China and abroad, such as Europe, the UK, and Japan, but also the strategic thinking of the development of high-speed rail of China. Furthermore, this book introduces the research on the some key technologies, covering various aspects of infrastructure, vehicles, signals, materials, dynamics, traction power supply, transportation organization, and so on. Although it cannot cover everything, this book gives an introduction of the research and technical work of Chinese scholars, which is very helpful for foreign scholars and industry to understand the new technology of Chinese high-speed rail. I hope that the publication of this book is able to attract more foreign scholars to participate in China's high-speed rail innovation, especially at the moment when China's high-speed rail is moving toward international prominence. Furthermore, I hope that it will serve to spread knowledge of China's recent remarkable railway progress and achievements.

Imperial College London Roderick A. Smith
January 2017

Preface

In 1865, the British merchant Durand constructed China's first railway in Beijing, starting the research on railway technology in China. In 2002, the "China Star" high-speed train achieved a top speed of 321 km/h in a test run. In just a few years, research in this field is on a fast track and parallel study in the most developed countries. A new era started in 2008, as symbolized by the first commercial high-speed railway from Beijing to Tianjing. In about seven years, 19,000 km of high-speed railway has been built in China, longer than the total length in the rest of the world, demonstrating top-rank capability in both research and manufacturing. There is no doubt that this advanced high-speed rail technology could not have been achieved without the research of the overseas pioneers. At the same time, what China now does in high-speed rail promotes development throughout the world. In other words, academic exchange of high-speed rail technology between China and other countries is of great importance to both China and the rest of the world.

In 2010, Mrs. Helen Zhang, Chief Editor of *Journal of Zhejiang University-SCIENCE A: Applied Physics & Engineering* (*JZUS-A*), invited Prof. Youtong Fang, Director of the High-Speed Railway Research Center in Zhejiang University, to be the guest editor in chief for the first special issue of *JZUS-A* to summarize cutting-edge high-speed railway technology in China. Up to now, three special issues have been published on this topic, and these have aroused worldwide interest.

Study of the high-speed train itself is at the core of this research, and recent research in China has focused on the theory and practice of wheel–rail, fluid–structure, and bow–net interactions. Wei-hua Zhang, Xue-song Jin et al. developed high-speed rail wheel–rail dynamics, Yun-min Chen, Xue-cheng Bian et al. carried out systematic study on subgrade settlement, Xue-ming Shao, Yao Zheng et al. developed the computational fluid mechanics method for the high-speed train, Weihua Zhang et al. analyzed the dynamic performance of the bow–net system, Liang Meng et al. developed the catenary contact wire with higher strength and higher conductivity, Limin Jia, Qinfen Lu, Xiaoyan Huang, Ping Tan, Gang Chen et al. did excellent research on transportation organization, traction power, communication signals, and train intellectualization. The international perspective is

also highlighted by the comprehensive review on the development of the China high-speed railway by Prof. Roderick A. Smith, the former Chief Scientific Advisor to Department of Transport, Fellow of the Royal Academy of Engineering, and Satoru Sone, Professor of Tokyo University, and Associate Director of the Japan Railway Technology Association.

The three special issues summarized not only in-depth research, but also the development route, especially charting the course of innovation that China has followed in high-speed rail technology. If we could collect all this work in one book, it would allow our international counterparts to better understand the research of Chinese scholars, and further promote the academic exchange of ideas and development. To this end, all the papers come from *JZUS-A*, and were reprinted in this book with permission from *JZUS-A* and Springer, as well as all authors.

I would like to thank the copy editors of the book, Ms. Hanfeng Lin and Ms. Xinxin Zhang. This book could not have been published without their hard work. I am also really grateful to every author—this book is a product of your intelligence and work. I also need to thank Prof. Roderick A. Smith for writing the foreword.

Finally, the publication of the book has also benefited from the support of the Natural Science Foundation of China (51637009, U1434202, 51477149, 51577166, 51507152), the "One belt one road" development open research alliance of science and technology, and the China Academy of West Region Development.

Qiushi Garden
January 2017

Youtong Fang

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About the Editors

Youtong Fang is a Professor at Zhejiang University. He is Chairman of the High-Speed Rail Research Center in Zhejiang University, Deputy Director of the National Intelligent Train Research Center, on the committee of the China High-Speed Rail Innovation Plan, and expert of the National 863 Program (China High Technology Development Program) in modern transportation and advanced carrying technology. He is also director of three projects of the National Natural Science Foundation of China (NSFC) and more than ten National 863 projects and Technology Support Programs. Recent work has been on electrical machines and drives. His research interests include permanent magnet (PM) machines and drives for traction applications.

Yuehong (Helen) Zhang is Chief Editor of the *Journal of Zhejiang University-SCIENCE A (Applied Physics and Engineering)*. Since 2010, under her planning, *JZUS-A* has published three special issues on China's High-Speed Railway Technology. She is also a Board Member of PILA/CrossRef (2014–2017), a Council Member of ALPSP (2011–2016), and Vice President of the Society of China University Journals. She has often been invited to give speeches at international publishing seminars, including the 4th World Conference on Research Integrity (www.wcri2015.org). She received a research grant from the Committee on Publication Ethics (COPE) in 2011 and has published many papers in international journals, including several short papers in *Nature*. In 2016, she published two books: *Against Plagiarism: A Guide for Editors and Authors*, published by Springer, and *Chinese Cultural Kaleidoscope*, published by Zhejiang University Press.

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