Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering)
ISSN 1673-565X (Print); ISSN 1862-1775 (Online)
www.zju.edu.cn/jzus; www.springerlink.com
E-mail: jzus@zju.edu.cn

Report:

Sustainability development strategy of China's high speed rail*

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http://dx.doi.org/10.1631/jzus.A1600747

1 Overview

The shortage of railway transport capability has restricted the development of China's economy. High speed rail is vital for the development of the passenger railway, because of its huge transport capacity, safety, comfort, all-day operation, environmentally-friendly operation, and its sustainability. Since 2004, the former China Ministry of Railways has introduced and assimilated advanced foreign technologies, and used this to improve the technologies of the construction of the high speed rail and train, and formed a nationwide cross-industry chain (Smith and Zhou, 2014).

According to the China "Mid-long Term Railway Network Plan" (NDRC, 2016), by 2020 the national railway operational mileage will reach 120 thousand kilometers. The double-track rate and electrochemical rate will reach 50% and 60%, respectively, and passenger transport and freight transport will be separate on main lines, of which the passenger dedicated line will reach 16 thousand kilometers. China's high speed rail network covers a vast territory and experiences complex geographical, geological conditions, and climate. The rapid development and unique network conditions of China's high speed rail make higher demands on the high speed rail technology system, especially the high speed train technology. These demands can be described as three main factors:

1. As high speed train manufacture and system integration capability improve, so also must the corresponding design, optimization, experimental and evaluation techniques, as well as other supporting techniques.

2. The basic theories of the high speed train must be developed based on research, and must be suitable for the environmental conditions and operational requirements in China.

3. It is difficult for the existing railway research system to satisfy the needs of innovation, integrate domestic research resources, establish high-level research, and exploit and experiment with platform and industry-study-research-application in a combined industry alliance of the type needed to support systematic introduction and operation.

Against this background, in February 2008, the Ministry of Science & Technology and Ministry of Railways of China jointly published "China High Speed Train Independent Innovation Joint Action Plan". Under the support of this plan, on Dec. 3, 2010, the new generation of high speed train CRH380AL having incorporated home-grown innovations, operated at 486.1 km/h high speed rail test speed on the Beijing-Shanghai line pilot segment. All the train's performance indices fully satisfied the design requirements, which demonstrated that China's high speed train technology had firmly established itself as the world's top level high speed train technology. By the end of 2011, the Beijing-Shanghai high speed rail was constructed and put into operation, representing, at that time, the world's longest mileage and highest technology standards with non-staged construction.

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* Project supported by the National Natural Science Foundation of China (Nos. 51637009, 51677171, 51577166, 51507152, and U1434202)
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2 Innovation achievements of China's high speed rail technology

The study and construction of high speed rail in China has been going on for nearly 20 years. The first stage was from 1990 to 2007, during which there were five big accelerations in the development of the national rail, and the introduction and absorption of high speed train technology from Germany, Japan, and France. The second stage is from 2008 until now, and this is the stage of independent innovation, the highlight of which is the launch of "China High Speed Train Independent Innovation Joint Action Plan". Supported by the Joint Action Plan, 25 key universities, 11 scientific research institutions, and 51 national laboratories and engineering technology research centers in China carried out a wide range of technical cooperation and exchange, and quickly tackled the key technical problems, so as to ensure the development of the new generation high speed train (MST, 2012).

2.1 Basic theory study of the high speed train

A high speed train system dynamics theory was proposed, the study objective was extended from the single carriage to the whole train, and the research scope was extended from wheel-rail interface to wheel-rail, bow net, and fluid-structure interaction. Corresponding research was carried out through non-linear dynamics modeling, and bench and track testing.

On wheel-rail interaction, research was carried out on the wheel-rail profile, the matching of materials and hardness, and the matching relation between lines and high speed trains, based on which the wheel-rail contact model under complicated conditions was established, and corresponding numerical methods were proposed and a high speed train wheel-rail contact relation under system dynamics was put forward (Zhao *et al.*, 2014).

On train fluid-structure, based on high speed train numerical calculation software and a support platform, analysis was carried out on lateral wind dynamics and aerodynamic moment in train operation, as well as safety analysis.

For the train bow net, the platform constructions, like the mechanism of the arc test rig and the pantograph vibration test rig, have been basically completed. The preliminary design of pantograph and catenary geometry and dynamic characteristics has been basically finished. The double arc spacing calculation formula was proposed for the high speed bow net system on the Beijing-Tianjin and Wuhan-Guangzhou Passenger Lines, and ensured the stability of double arc at speeds under 380 km/h.

For train vibration and modal analysis, experiments were carried out on slab track at 350 km/h on the Beijing-Tianjin Intercity High Speed Line, the Wuhan-Guangzhou Passenger Line, and the Zhengzhou-Xi'an Passenger Line. These examined the system vibration phenomenon and characteristics caused by the periodical ratio relationship between wheel circumference, slab length, rail fixed length, and bridge span length, and this provided the basis for the design and structural optimization of the new generation high speed train. In addition, the general high speed train comfort simulation platform was established through analysis of in-car comfort indices.

2.2 Design and manufacturing technologies of the high speed train

During construction and improvement of a digital collaborative simulation platform, the technology architecture covering the design and experimental platform of the train set assembly, and the design of the train body and bogie are formed.

The development of the high speed bogie digital design platform, the experimental platform, and the digital processing platform are completed; the batch production capability of the high speed train bogie is now achieved. The system now uses a double-H welding bogie frame and bogie-integrated cast aluminum alloy transition corbel, a hollow car axle, and an aluminum alloy gear box structure, and this significantly reduces unsprung weight and wheel-rail dynamic interaction. A high flexibility air spring, a two point air spring control system, and an adjustable length lateral rolling torsion bar device are adopted to improve the high speed operation quality of the bogie. An elastic suspension traction drive structure is adopted to improve the comprehensive dynamic performance. Wheel-set guiding, an air spring, and a traction motor emergency system ensure the safety and reliability of the bogie.

According to the operational requirements of a high speed train, aerodynamic performance evaluation of 20 design schemes of train head was carried out, to help finalize the design of the CRH380A series high speed train head shape. The experiments on the Wuhan-Guangzhou, and Zhengzhou-Xi'an high speed lines demonstrated that the total operational resistance of an eight-car train set at 350 km/h decreased 6.1%, the noise level decreased 7%, the tail lift force reduced 51.7%, and the lateral force reduced 6.1%, thus realizing the optimization design of the new generation of high speed train, which provides important support for train head shape design.

The 1:8 model of the CRH380AL/BL series high speed train and aerodynamic noise evaluation of key components were accomplished in a high speed train aerodynamic acoustic wind tunnel. The adaptability of high speed train aerodynamic noise measurement technology was studied, and fully validated that the noise measured in the wind tunnel accurately reflects the train's aerodynamic noise in magnitude and frequency characteristics. The upgrading scheme for a pneumatic acoustic wind tunnel has successfully passed systemic proof, and it is estimated that the experimental speed in the wind tunnel will exceed 420 km/h.

The high speed train aerodynamic numerical simulation platform is capable of modeling a 16-car full-size high speed train and subgrade, bridge, tunnel, platform, and similar work conditions. Currently, vehicle appearance, new head shape series, and aerodynamic performance evaluation and optimization of the CRH2, CRH3, CRH380 series high speed train and higher speed test train under severe work conditions (cross wind, tunnel crossing) are carried out on this platform, which provides key systemic and theoretical support for resistance and noise reduction.

In car body modal optimization, there have been many new vibration reduction structures and materials, so as to achieve the required vibration reduction effects. On the premise of a light car body, the first-order vertical bending frequency of a car body modal of vibration achieves a 10% increase and reaches 16.8 Hz; the first-order natural frequency of the floor increases by 22% and reaches 40.5 Hz; the first-order natural frequency of the end wall increases by 21% and reaches 48.2 Hz.

Concerning car body aerodynamic load, the multi-component high-frequency large-amplitude alternating aerodynamic load was studied, and air-tight strength and tightness control standards for an operational speed of 350 km/h and above were established; new designs of cross-section and bearing structure were adopted to optimize the pressure control method in a car; the air tightness of the car body increased from ±4000 Pa to ±6000 Pa, the pressure variation rate is controlled below 2‰ atmosphere, and the maximum variation amplitude is controlled below 8‰ atmosphere pressure.

The design, simulation, and experimental platform of the traction drive system and brake system were established, and the demonstration base, pilot line, and production line for a high speed train were constructed. This is capable of integrated manufacturing and mass production. The strength and reliability of bow net components were improved, and the dynamic current-receiving quality of the pantograph and catenary was increased (Ma *et al.*, 2011).

The Chinese Train Control System (CTCS)-3 train operation control system set was completed, and a complete CTCS-3 train control system validation process was established. A sub-system special test, a lab integration test, an on-site installation, test and commissioning (ITC) test, an alignment test, and trial operation were completed. Problems such as electromagnetic interference, wireless communication interrupt, and Global System for Mobile Communications-Railway (GSM-R) network optimization were solved. This helped verify the reliability, safety, and stability of the system and improved the general technical level of the CTSC-3 train control system.

High-strength high-conductivity contact wires with 37 kN tension force were developed and operated in the Beijing-Shanghai guide line, the strength of which reaches 570 MPa and the conductivity reaches 75% IACS. The dedicated "2×27.5 kV" switch cubicle realized large scale domestic production.

The high speed rail society-economy affected zone model was built, and a high speed train passenger transport demand database was established, so as to accomplish high speed rail basic database sharing and a service platform and the development of a high speed rail passenger transport demand data service sub-system. The high speed rail resource optimization system was established and the "Rail Lines Video Query System" based on high speed rail basic data sharing and service platform is able to provide data support and supportive decision-making for railway equipment management, scheduling command, rescue and relief work, and accident rescue.

The main pieces of equipment for a high-speed inspection car were developed, including a video device, a measurement device at the wiring interval, an automatic train control (ATC) determinator, a train wireless equipment measurement device, and a determination station; there was also an axle load transverse pressure measurement axis, an axle box acceleration measurement device; a track vertical displacement and vehicle shaking measurement device, line condition monitoring equipment, wheel load transverse pressure data processing equipment and video devices; stringing abrasion offset height measurement device, collector state monitoring device, pantograph observation device; electric power measurement station, data processing equipment, a power supply circuit measurement device, a train number ground measurement device, high speed electric multiple unit (EMU) technology, the ground monitoring data analysis technology, a high-speed mobile comprehensive detection technology system including the open management and application technology of the high speed railway infrastructure testing data.

3 Engineering application of domestic high speed train

3.1 Opening and operation of the Wuhan-Guangzhou high speed train

On Dec. 26, 2009, the Wuhan-Guangzhou high speed line was put into operation with a domestic high speed train, which created the record of passing speed of 350 km/h in tunnels, 350 km/h double train in connection, and a double pantograph receiving current.

The Wuhan-Guangzhou high speed line is the one under the world's most complicated working conditions. Its total length is 1068 km with 226 tunnels. The longest tunnel is Liuyanghe Tunnel at 10 km, and the inner and outside temperature difference of the tunnel is large. The percentage of bridge and tunnel is 67%. The Wuhan-Guangzhou high speed rail features high operation speed, high passing speed, and high passing density. These unprecedented operating conditions pose first-ever challenges for a high speed train.

The main technology innovations are as follows:

In terms of long distance operation: (1) the reliability optimization of suspending items in view of high speed complex air turbulence (including suspending below the train like a skirtboard, or a windshield); (2) with reference to complex aerodynamic effects, improvement of the car body air tightness, and optimization of the car body structural strength design; (3) aiming at continuous high speed operation, optimization of the locate mode, location parameter, and secondary suspension parameters, and improvement of the coupling relationship between wheel and rail, to effectively control abrasion and wheel/rail interaction force; (4) in a complicated vibration environment, improvement of the structural strength design of the bogie and increase of the fatigue life by a factor of two.

In terms of train air tightness: improve the air tightness of the whole train. When two trains pass each other with an operation speed of 350 km/h in a tunnel, it takes 252 s for the in-car pressure to reduce from 4000 Pa to 1000 Pa while the standard of pressure reduction is above 50 s; the pressure variation in-car is less than 1000 Pa, and the pressure variation rate in-car is less than 200 Pa/s.

In terms of vibration and noise reduction: optimize the structural parameters of the bogie and systematically optimize the modal matching relation among bogie, car body, and line. For example, car sickness (0.5 Hz–1 Hz) and tiredness (8 Hz–10 Hz); track periodic turbulence: 6.5 m, 32 m, and 100 m.

In terms of wheel/rail matching: continuously track the performance difference of various track profiles after abrasion with wheel tread, detecting the sensitive response region of the wheel/rail in high speed conditions in an innovative manner, and achieve a series of solutions (rolling circle, contact point, rail grinding, and rotary wheel tread).

In optimization of aerodynamic performance and resistance: operation resistance is reduced by 6%; currently there are 66 trains operating on Wuhan-Guangzhou line, and the annual electricity saving is 120 million kWh.

3.2 Opening of the Beijing-Shanghai high speed line

On Apr. 27, 2010, the first sample car of the "Harmony" CRH380A high speed train came off the assembly line successfully in China South Locomotive and Rolling Stock Co. Ltd. (SCR) Qingdao Sifang. The CRH380A high speed train features 350 km/h operational speed and 380 km/h maximum speed, and adopts a low resistance streamline head profile, high air tightness, and air-tight car body; the advanced acoustic vibration reduction technology and innovations in strong green power traction system technologies not only ensure stable low-noise operation, but also realizes low resistance, lightweight, regenerative braking, green power, and zero release. On Dec. 3, 2010, the CRH380A high speed train created an operation test speed of 486.1 km/h. The new generation of domestic high speed train came into service and provides key technology elements for the Beijing-Shanghai high speed line.

On June 30, 2011, the Beijing-Shanghai high speed line completed construction and was put into operation. The total length of the Beijing-Shanghai high speed line is 1318 km with a design speed of 350 km/h. This is the world's first high speed line with such a long mileage and high technology standards; the whole line fully adopts the technology and equipment of the domestic high speed train, which demonstrates the highest level of China's high speed rail and train.

3.3 Domestic 400 km/h comprehensive inspection car came off the assembly line

The comprehensive inspection car is important for periodic, comprehensive, and high speed detection of a high speed train with speeds above 200 km/h, and has the comprehensive inspection ability of railway infrastructure such as rail, catenary, and communication signals.

In March 2011, the CRH380B-00 high speed comprehensive inspection train, developed by the China Academy of Railway Sciences and Tangshan Railway Vehicle Co. Ltd., came off the assembly line and was put into operation. The designed maximum test speed of the train is 500 km/h, the synchronous detection speed reaches more than 350 km/h, and the maximum test speed reaches 400 km/h, and the train has the real-time detection ability of hundreds of parameters like high speed rail wheel/rail dynamics and vehicle dynamic response, catenary, communication, and signals.

Relying on the comprehensive inspection car, the ground monitoring data analysis and processing center for comprehensive evaluation and decision support were established, expert analysis diagnosis, ground demonstration, data storage, and management systems were developed, and the open management platform for domestic high speed rail infrastructure was built, all of which provide experimental verification for track irregularity standard management. Also developed are the Beijing-Shanghai high speed line irregularity spectrum, a train/track system dynamic characteristic evaluation method based on the generalized energy method, a train/track system safety evaluation method using axle box acceleration rate, a train track dynamic simulation model, the relationship between contact line irregularity and bow net dynamic response, and a transponder message evaluation method for high speed rail above 350 km/h. At the same time the dynamic debugging and functional verification of the wireless transfer system and ground demonstration system were carried out.

4 Development prospect of China's high speed rail technology

The construction of China's high speed rail provides a convenient, economic, rapid, comfortable, and ecological mass transport tool for our people, and it also affects the regional economic pattern of China (Jin, 2014). It has had a warm reception from our people, industry, investors, and the government. The next 10 years is an important period of China's high speed rail construction and development. In 10 years' time, the high speed rail network covering China's mainland will be almost completed, and the high speed rail will be the first choice for mid-long journeys. It will also promote the development of China's economy.

4.1 China's high speed rail network plan in the next 10 years

On June 29, 2016, the State Council Executive Meeting approved in principle the new "Mid-long

Term Railway Network Planning", which requires the construction of a comprehensive transport system integrating road, navigation, and aviation, providing support for the development and upgrading of economy and society with the artery of transportation. It will involve construction of a high speed railway network with "Eight Longitudinal" featuring the seaside and Beijing-Shanghai, "Eight Horizontal" featuring land bridge and riverside, and intercity railways as a supplement. It will form a 1–4 h transport circle between large-medium cities, and 0.5–4 h transport circle within urban clusters. At the same time, it will nurture and develop new economy formats of high speed rail, promote the regional exchange and cooperation and resource optimization, accelerate the industrial gradient transfer, and drive the transformation and upgrading of the manufacturing industry and economy as a whole.

The detailed planning scheme includes:

First, construction of the "Eight Longitudinal and Eight Horizontal" high speed rail main pathways (Fig. 1). The "Eight Longitudinal" pathways are: the seaside path, Beijing-Shanghai path, Beijing-Hong Kong (Taiwan) path, Beijing-Harbin-Beijing-Hong Kong-Macao path, Hohhot-Nanjing path, Beijing-Kunming path, Baotou (Yinchuan)-Haikou path, and Lanzhou (Xi'an)-Guangzhou path; the "Eight Horizontal" pathways are: the Suifenhe-Manzhouli path, Beijing-Lanzhou path, Qingdao-Yinchuan path, land bridge path, riverside path, Shanghai-Kunming path, Xiamen-Chongqing path, and Guangzhou-Kunming path.

Second, there will be expansion of the regional railway conjunction line. Based on the "Eight Longitudinal and Eight Horizontal" main pathways, it will plan and lay out high speed rail regional connections, in order to further improve and increase the coverage of the high speed rail network.

Third, there will be development of the intercity passenger line. While taking advantage of the high speed rail and the conventional rail with intercity service, it will plan and construct the city cluster intercity passenger railway effectively linking medium-big cities and town centers, and supporting and leading the development of new urbanization.

The new projects of high speed rail main paths adopt the 250 km/h and above standards in principle, in which 350 km/h standards were adopted for lines connecting large cities, with large population density, and a developed economy. The regional railway lines adopt 250 km/h and below standards. Intercity lines adopt 200 km/h and below standards.

According to the new railway network planning, up to 2020, a batch of major landmark projects will be completed and put into operation, in which high speed rail has 3000 km in length, covering over 80% of big cities. By 2025, the railway network will reach 175 thousand kilometers, in which the high speed railway will account for 38 thousand kilometers.

4.2 Study and deployment of China's high speed rail research in the next 5 years

During the 13th Five-Year Plan, China launched the "Advanced Rail Transit" key program of the national key research and development plan. The main contents are given below.

4.2.1 Safety assurance technology of the rail transit system

There will be study of the sensing, evaluating, and alerting technique of the rail transit operational environment status, comprehensive monitoring and assurance technique of public right of way (ROW), decoupled and comprehensive safety assurance technique of the rail transit system, and the comprehensive safety assurance technique of the regional rail transit system, so as to form a rail transit safety-related holographic intelligent perception, fast identification, risk evaluation, early warning and emergency response, and constitutive security of carrying equipment. There will be construction of a comprehensive rail transit safety assurance technique platform including safety prediction evaluation theory and method, sets of safety standards techniques and regulations, and a technology support system. There will be construction of a rail transit safety assurance and emergency management integrated management platform. It should have the capability to lower rail transit safety accidents caused by technical issues by 50%, and effect a switch to active safety assurance.

4.2.2 High energy efficiency of traction power supply and transmission key techniques of rail transit

There will be a revolution in traction drive technology. This will come about through the study of

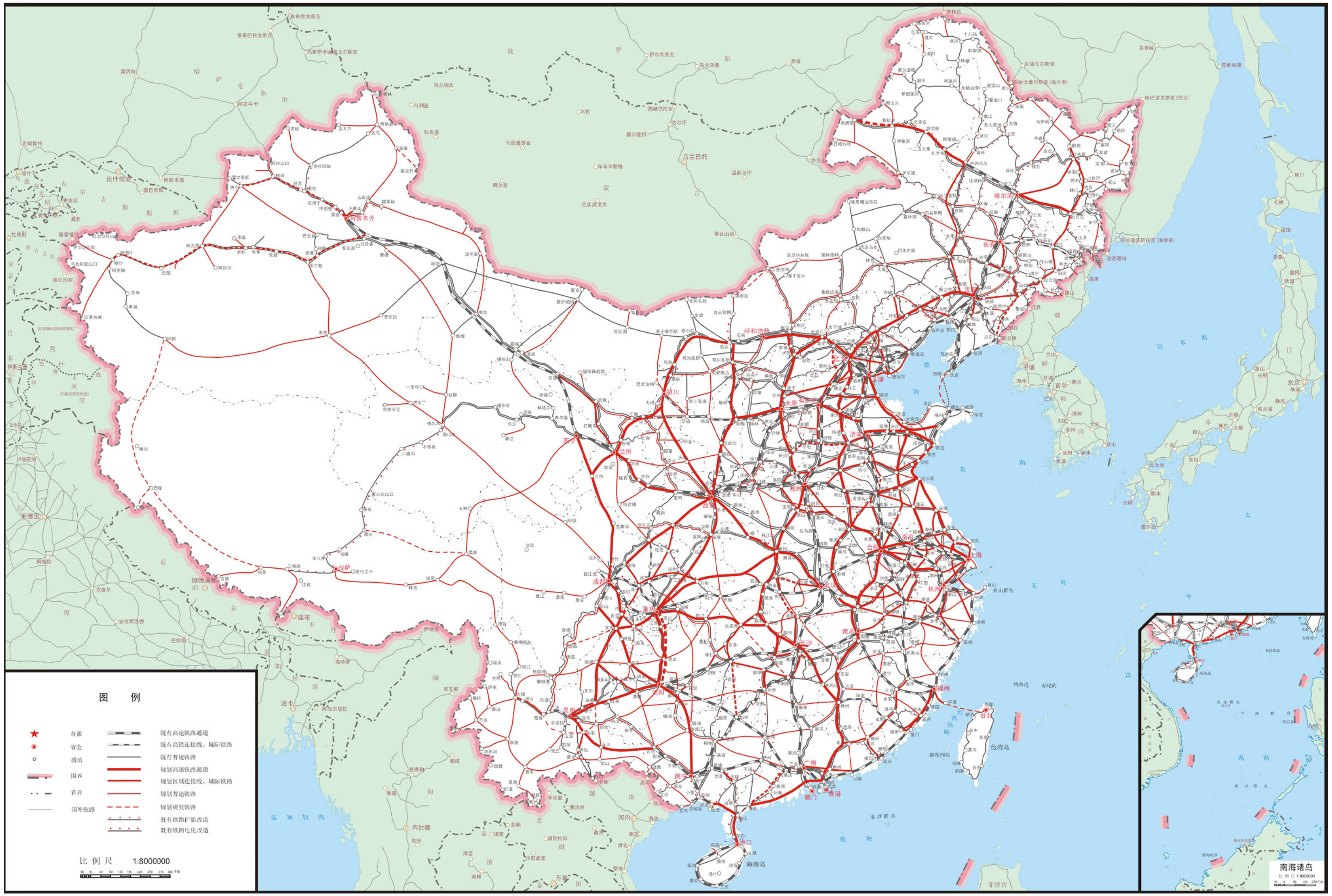

Fig. 1 Mid-long term railway network planning in China (http://www.gov.cn/xinwen/2016-07/20/content_5093165.htm)

Translation of important places in "Eight Longitudinal and Eight Horizontal": 北京: Beijing, 上海: Shanghai, 香港: Hong Kong, 台湾: Taiwan, 哈尔滨: Harbin, 澳门: Macao, 呼和浩特: Hohhot, 南京: Nanjing, 昆明: Kunming, 包头: Baotou, 银川: Yinchuan, 海口: Haikou, 兰州: Lanzhou, 西安: Xi'an, 广州: Guangzhou, 绥芬河: Suifenhe, 满洲里: Manzhouli, 青岛: Qingdao, 厦门: Xiamen, 重庆: Chongqing.

Translation of the legend: 首都: capital, 省会: provincial capital, 城镇: town, 国界: national boundaries, 省界: provincial boundaries, 国外铁路: foreign railway, 既有高速铁路通道: existing high speed rail, 既有高速连接线、城际铁路: existing high speed rail connection inter-unban railway, 既有普速铁路: existing conventional rail, 规划高速铁路通道: planned high speed rail, 规划区域连接线、城际铁路: planned regional connection inter-unban railway, 规划普速铁路: planned conventional rail, 规划研究铁路: planned research rail, 既有铁路扩能改造: expansion of existing railway, 既有铁路电化改造: electrification of existing railway the following list of research topics: the study of virtual in-phase flexible power supply technology, the catenary system and power supply device with high flow characteristics, efficient converter device of rail transit train, contactless power supply techniques of rail transit, key techniques and equipment development of contactless power supplied urban rail vehicle, key techniques and equipment development of interval power-supplied rail transit, master techniques regarding the train high performance flexible power supply, high conductivity wire materials, reducing the consumption of the converter, comprehensive usage of regenerative energy, traction converter technology based on new topological transformation, new materials and new structures, the realization of a virtual in-phase power supply, and high efficiency traction converter technology and in-car equipment system. A comprehensive grasp of new power batteries, super capacitor energy storage application techniques, and car-ground integrated static dynamic contactless/wireless current collection technique will form safe, efficient, and economic rail transit hybrid energy storage and traction drive systems suitable for a multi-power supply mode and complicated application conditions (Huang *et al*., 2015).

4.2.3 Life cycle maintenance technique of rail transit

This will come about through the study of rail transit integrated design-manufacture-operation technology concerning whole life cycle cost, rail transit train environmental-friendly technology, and the decoupled and efficiency improvement key technology in the rail transit energy consumption procedure, to form the whole life cycle design criteria integrating design, manufacturing, and operation. It will develop the integrated key technology concerning whole life cycle rail transit with environmental-friendly, comprehensive cost control, and efficiency improvement, realize the rail transit whole life cycle low cost, be environmental-friendly, and offer wholescale efficiency improvement (Zhang *et al.*, 2015).

4.2.4 Guided transport system mode diversification and equipment study

Through the study of self-guided urban rail transit train system technology and equipment, and self-adjusted bogie key technology, the aim is to master the virtual rail guided transport system technology, to master the structural and parameter adapting and control techniques of wheel-rail bogie and line, and to create the supporting technology and equipment system of design, manufacture, evaluation, delivery, and operation of a guided transport system suitable for the town diversity of our country.

4.2.5 Key technology for 400 km/h and above high speed passenger transport equipment

Through the study of train multi-effect coupled and smart control technology, the comprehensive comfort level control based on noise active control, the "gravity-resistance-driving force" multi-objective balanced energy saving technology, high safety factor walk system, structural fire proofing and electromagnetic compatibility technology, the key train technologies of various structural walk system, and transnational interconnected high speed train equipment and operation maintenance system, the aim is to master the key technologies concerning system integrated, car body, bogie, traction and braking, power supply, train control, operational control, system operation and maintenance satisfying the needs of "One Belt One Road", and transnational interconnected adaptability and criteria system, and accomplish the study of high speed train and various structural trains with a speed level of 400 km/h and above. At the same time we will systematically deepen and establish the key technology system regarding high speed train multi-effect enhanced coupling and control, environmental-friendly enhancement, whole life cycle design and integration, reliability, availability, maintainability, and safety (RAMS) comprehensive performance improvement, to create the improved adaptability and enhanced technology of existing infrastructure and equipment, study the high speed train system with operation speed of 400 km/h and above which is suitable for the high speed rail infrastructure in China.

4.2.6 Railway comprehensive effectiveness and service level improvement under high speed rail network conditions

Through the study of railway passenger freight service mode design and resource allocation under high speed rail network, benefit and service level improvement technology of railway passenger freight transport, railway network operation assurance technology and operation, and service cooperative decision and support system, we will form the transportation technical standards supporting rail network comprehensive effectiveness and service level improvement and a new railway transportation engineering technology system, and realize and improve the "One Belt One Road" transnational transport and international competiveness.

4.2.7 Regional rail transport co-transport and service technology

Through the study of regional transport comprehensive effectiveness improvement technology, regional rail transport safety assurance technology, and regional rail transport information service technology and system, we will form the regional rail transport multi-model co-transport, safety assurance, information service integrated technology, and system platform, and satisfy the needs of regional rail transport comprehensive effectiveness and service level, to support the regional rail transport integrated transportation and service.

4.2.8 Space-air-train-ground integrated rail transport safety and control technology

Through the study of rail transit dedicated static and dynamic hang platform system technologies, the space-air-train-ground-information integrated rail transit dedicated network technologies, rail transit system status information integration and processing techniques, vehicle mobile interconnection technology based on dedicated network, sparse low capacity road network train operation control system key technologies, and dynamic block system based on location information, we will form the dedicated static and dynamic air platform design, manufacture, operation and maintenance technology, form the dedicated space-air-train-ground integrated transportation and monitoring network which satisfies its interaction operation needs, form the multi-level multi-granularity high-dimensional holographic technology which satisfies the large-scale, all-weather, full coverage, all around live monitoring needs of rail transit and its safe operation environment, form large-scale high-dimensional rail transit safety information monitoring and integration, analysis and application technology, and form high-property low-cost, multi-functional new safety assurance mode of the wide-range sparse road network. At the same time, we will develop the key technologies concerning route control based on multiple information integration and location technique, multi-path information transmission and control, dynamic interval configuration braking and safety protection, develop, new train operation and control system with high maintainability featuring small-scale low-density rail-side equipment and dynamic interval configuration, satisfying the needs of safety, efficient operation and sustainability of national defensive western and backcountry low-density transport network.

4.2.9 Rail transit freight transportation rapid technology and equipment studies

Through the study of multi-mode freight transportation adapter system technology, key technologies and equipment study of 160 km/h freight train, road-rail convenient transport key technologies and equipment, and 250 km/h and above freight trains, we will form the rapid and convenient, multi-mode, high-speed standard regulation, and technique system, to satisfy the needs of national defense mobility and support the rapid, efficient, and low-cost railway-oriented comprehensive transport system.

4.2.10 Key technology study and equipment development of a maglev transport system

Through the study of key technologies and equipment study of the mid-speed maglev train, mid-speed train synchronous traction control techniques study, operation control technology of mid-speed maglev transport, independent technology integration demonstration model, and comprehensive evaluation of high speed maglev transportation system, we will fully master the key technologies of high-efficiency high-reliability suspension traction and operation control of mid-speed maglev, including hybrid suspension and synchronous traction, and construct a mid-speed maglev test line. We will fully master the key technologies of high speed maglev, break the limitation of foreign intellectual property, to realize the independence of high speed maglev, and be able to independently assemble a mid-long high speed maglev transportation system.

Through the implementation of this project, the 400 km/h and above high speed train and corresponding system will be delivered, and the life cycle operation cost will aim to be reduced by 20%.

5 Conclusions

The expansion of China's high speed rail demands higher requirements for the study of high speed rail technology. Research can be further carried out in the following areas (NSFC, 2016):

1. Long term service regression study of slab track;
2. High speed rail freight transport technology;
3. High speed rail driverless technology;
4. High speed rail failure monitoring, diagnosis and smart operation technology;
5. High speed rail optimized operation;
6. Study and development of new generation high speed rail equipment.

Currently, the high speed rail mileage in China has surpassed the total of all other countries. By 2025, the high speed rail operation mileage will reach 38 thousand kilometers. Meanwhile, other countries are studying and investing in the construction of high speed rail. It becomes increasingly important to improve the safety, comfort, economy, and mobility of the high speed railway. Obviously, to further study the high speed rail technology is not only necessary in itself, but also promotes the development of corresponding technology and industry.

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中文概要

题　目：中国高速铁路的可持续发展战略

概　要：2008 年以来，通过引进和消化国外高速铁路先进技术，联合设计生产和在此基础上的再创新，中国高速铁路技术进入了世界前列，并建成了世界上规模最大，技术水平最高的高速铁路网，大幅改善了中国的交通状况，带动了区域经济和装备制造业的发展。新的中长期铁路网规划的发布和“一带一路”及中国铁路“走出去”战略的实施，给高速铁路技术提出了新的要求。未来需要将现代科学的最新进展与高速铁路建设、运营、维护和管理的工程进一步结合，通过创新支撑中国乃至世界高速铁路的可持续发展。

关键词：高速铁路；技术创新；可持续发展