Ⅰ. Subject Overview: This section includes information such as the historical development of the subject, categories of subject authorization, key subject awards or "Double First-Class" construction status, subject evaluation rankings, and international subject rankings (ARWU, QS, USNEWS, ESI), etc.

In the 2023 "ShanghaiRanking's Best Chinese Academic Subjects", the university had 23 subjects listed. Among them, Transportation Engineering and Systems Science maintained their top position, being recognized as "Top Subjects in China." Transportation Engineering has ranked No. 1 nationwide for six years, while Systems Science has ranked first for five years since its debut in 2019.

Transportation Engineering was also listed in the 2023 "ShanghaiRanking's Global Ranking of Academic Subjects," ranking first in the world for the fifth time.

Ⅱ. Subject Positioning and Goals, Directions, and Strengths

The Vehicle Operation Engineering subject at Beijing Jiaotong University is distinguished by its focus on "Rail Transportation" and is centered around "Vehicle Safety and Environmental Protection." Aligned with the university's "Double First-Class" construction in "Smart Transportation," this subject benefits from various research and teaching platforms, including the Ministry of Education Key Laboratory for Advanced Manufacturing and Measurement & Control Technology of Vehicles, the Ministry of Education Engineering Research Center for Structural Reliability and Operational Testing Technology of Rail Vehicles, the National Accredited Laboratory for Structural Strength Testing, and the National Demonstration Center for Mechanical Engineering Experimental Education.

Focusing on rail vehicles and transportation tools, the subject aims at achieving high speed, heavy load, and intelligence. By integrating design, operation, and safety assurance technologies, it fosters high-level talent training and scientific research, developing four distinctive research directions.

1. Theories and Technologies of Vehicle Operation Safety

This research direction focuses on vehicle state safety protection, safety simulation, vehicle speed safety control, vehicle structural reliability assessment, structural modeling and algorithms of optimization design, safe operation and management of vehicles, traffic safety equipment engineering, safety detection and monitoring technologies, as well as the operational stability and ride comfort of vehicles. It also involves big data mining, fault diagnosis, and hybrid modeling aimed at proactive maintenance of vehicles.

2. Detection and Control of Vehicles and Infrastructure

This research direction focuses on damage identification, fault diagnosis methods, and condition assessment technologies for key components of rail vehicles. It explores theories and applications for predicting the lifespan and state-based maintenance of key components using big data analysis and artificial intelligence. The research also delves into non-destructive testing technologies based on principles such as ultrasound, structured light, machine vision, and vibration modal analysis. Additionally, it involves safety condition detection of infrastructure, including seamless rails, tracks, and tunnels, with an emphasis on theoretical research, technological innovation, and engineering applications. The direction also investigates environmental detection technologies based on video, LiDAR, microwave radar, and develops foundational theories and application technologies for intelligent environmental perception using deep learning and knowledge graphs.

3. Operating Environment and Advanced Power Technologies of Vehicles

This research direction covers the study of internal and external thermal environments of vehicles, the mechanisms of fuel atomization, mixing, and combustion in engines, as well as emission control technologies for vehicle engines. It also includes research on advanced theories and technologies for clean vehicles and power systems, theories and technologies for new energy vehicles, vehicle energy management and control technologies, and the theories and technologies of novel combustion systems.

4. New Materials Science and Technology for Vehicles

This research direction primarily focuses on the design and fabrication methods of new materials for vehicles, including fundamental theories and key technologies related to strengthening mechanisms, microstructure control, performance evaluation, service characteristics, and failure mechanisms. It also covers the application technologies and scientific theories of advanced steel materials, ceramics and ceramic matrix composites, metal matrix composites, and multifunctional integrated materials in various types of vehicles.

III Faculty Situation in the Discipline

Zujun Yu: Professor and Ph.D. advisor, President of Beijing Jiaotong University, Director and Chief Scientist of the Frontiers Science Center for Smart High-Speed Rail Systems, and a member of the Academic Degrees Committee of the State Council for Transportation Engineering. He was selected for the Ministry of Education's New Century Excellent Talents Program and is a recipient of the Mao Yisheng Railway Science and Technology Award as well as the Zhan Tianyou Science and Technology Achievement Award. Professor Yu has long been engaged in research and teaching in the field of intelligent perception and operation control of rail transit. He has published over 80 SCI/EI papers and holds more than 20 invention patents. He has received several national awards for graduate teaching, including one first prize and two second prizes. His course "Measurement and Control System Design" was recognized as a national first-class course. Additionally, he has received one first prize from the Ministry of Education's Science and Technology Awards, one second prize from the Beijing Municipal Science and Technology Awards, and two first prizes from the China Railway Society Science and Technology Awards.

Hongmei Shi :Professor and Ph.D. Advisor: Recipient of the Beijing Excellent

Teacher Award, Beijing Teaching Master Award, and the Baogang Excellent Teacher Award. With a long-standing focus on the research areas of condition monitoring, fault diagnosis, and health management of rail transit vehicles and infrastructure, they have published over 60 papers and hold more than 10 authorized invention patents. They have also been awarded two first prizes from the China Railway Society Science and Technology Awards and one second prize from the Beijing Municipal Science and Technology Progress Awards.

Liqiang Zhu: Professor and Ph.D. advisor, selected for the Ministry of Education's New Century Excellent Talents Program, and recipient of the Zhan Tianyou Railway Science and Technology Award. He has long been engaged in research on intelligent detection in rail transit, having published over 100 papers and holding more than 20 authorized invention patents. He has also received two first prizes from the China Railway Society Science and Technology Awards and one second prize from the Beijing Municipal Science and Technology Progress Awards.

Baoqing Guo: Professor and Ph.D. advisor, recognized as a Beijing Youth Teaching Master and a recipient of the Beijing Youth Talent Award. He has been dedicated to teaching and research in the fields of intelligent perception of rail transit infrastructure conditions and machine vision detection. He has received two first prizes from the China Railway Society Science and Technology Awards, one second prize from the Beijing Municipal Science and Technology Progress Awards, one second prize from the Beijing Teaching Achievement Awards, and one second prize from the China Instrument and Control Society Higher Education Teaching Achievement Awards.

Qiang Li: Professor and Ph.D. advisor, Director of the National Accredited Laboratory for Structural Strength Testing at Beijing Jiaotong University, and Director of the Key Laboratory for Structural Reliability of High-Speed EMUs in the railway industry. He has been awarded the State Council Special Allowance and the title of Outstanding Young Railway Science and Technology Talent. He has received one second prize in the National Teaching Achievement Awards and one first prize in the Beijing Teaching Achievement Awards, along with four first prizes in provincial and ministerial-level science and technology awards. Qiang Li has accumulated extensive research and applied achievements in the field of structural reliability of rail vehicles and other transportation equipment.

Wenjing Wang: Professor and Ph.D. advisor, Associate Dean of the School of Mechanical and Electronic Control Engineering at Beijing Jiaotong University. She has long been engaged in research on structural fatigue reliability of rail vehicles. She has received several honors, including the Baosteel Excellent Teacher Award, the Zhijin Teaching Award for Outstanding Young Teachers, "Top Ten Female Talents of Jiaotong University," and the Ministry of Transport's Outstanding Young Science and

Technology Talent Award. Her accolades include one Special Prize in the National Science and Technology Progress Awards, one First Prize in the Ministry of Education's Science and Technology Progress Awards, six Special Prizes and First Prizes from the China Railway Society Science and Technology Awards, and multiple provincial and ministerial-level honors.

Binjie Wang: Professor and Ph.D. advisor, Chair of the Department of Rail Vehicles in the School of Mechanical and Electronic Control Engineering at Beijing Jiaotong University. He has long focused on research in the structural fatigue reliability of rail vehicles. His awards include the First Prize in the Ministry of Education's Science and Technology Progress Awards, the Second Prize from the China Transport Association Science and Technology Awards, the Zhan Tianyou Railway Science and Technology Special Award, the Special Prize from the Railway Society Science and Technology Awards, the First Prize in the Urban Rail Association Science and Technology Progress Awards, and recognition as a Beijing Youth Science and Technology Talent.

Guangxue Yang: Professor and Ph.D. advisor, Deputy Director of the National Accredited Laboratory for Structural Strength Testing at Beijing Jiaotong University, and Deputy Director of the Key Laboratory for Structural Reliability of High-Speed EMUs in the railway industry. He has long been engaged in research on the structural fatigue reliability of rail vehicles. He has been recognized as an Outstanding Young Science and Technology Talent by the Ministry of Transport and has received one Special Prize in the National Science and Technology Progress Awards, one Special Prize and three First Prizes in provincial and ministerial-level awards, and the Zhan Tianyou Railway Science and Technology Award - Innovation Team Award.

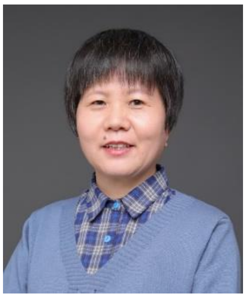
Guoxiu Li: Professor and Ph.D. advisor, selected as a New Century Excellent Talent by the Ministry of Education. He is the Director of the Development Planning and Subject Construction Office at Beijing Jiaotong University, Director of the Beijing Key Laboratory for New Energy Vehicle Powertrain Technology, and a member of the Academic Committee for the Beijing Key Laboratory for Clean Vehicles. He also serves as a member of the Combustion Division of the Chinese Society of Engineering Thermophysics, the Thermodynamics and Engineering Applications Committee of the China Energy Research Society, and the Fifth National Engineering Professional Degree Graduate Education Advisory Committee. He has received two second prizes in the National Education Achievement Awards and two first and two second prizes in provincial and ministerial-level science and technology progress awards.

Zhi Ning: Professor and Ph.D. advisor. He is a member of the After-treatment Technology Division of the Chinese Internal Combustion Engine Society, a member of the Aviation Engine Division of the Chinese Internal Combustion Engine Society, and a council member of the Beijing Internal Combustion Engine Society. His research primarily focuses on advanced automotive power technologies. He has received a First Prize in provincial and ministerial-level Science and Technology Progress Awards.

Jie Liu: Professor and Ph.D. advisor. His research focuses on fundamental combustion theory, advanced internal combustion engine combustion technologies, thermal safety and management of lithium-ion batteries, and the design and development of fuel cells. He currently serves as a member of the Youth Working Committee of the Chinese Internal Combustion Engine Society, a member of the Fuel Cell Division, a member of the Gasoline Engine Division, a member of the Fuel and Lubricants Division, and a council member of the Beijing Internal Combustion Engine Society.

Yang Zhou: Professor and Ph.D. advisor, and head of the research team on specialized materials for rail transit. His primary research focuses on the design, fabrication, evaluation, and application of metal matrix composites, ceramics and ceramic matrix composites, and composite phase change materials. He has led several National Natural Science Foundation projects and has served as a reviewer for the National Science and Technology Awards, Beijing Science and Technology Awards, National Natural Science Foundation, and intergovernmental cooperation projects.

Shibo Li: Professor and Ph.D. advisor. His research focuses on easily machinable conductive ternary layered MAX and MAB ceramics, new materials and key components for high-speed trains, and related areas. He serves as a peer reviewer for the National Natural Science Foundation, an evaluator for the China Scholarship Council's government-sponsored programs, and an expert for the Ministry of Education, Ministry of Science and Technology, Beijing Municipal Science and Technology Bureau, and other provincial science and technology agencies. He is also an associate editor of the International Journal of Applied Ceramic Technology and a member of the editorial board for Coating.



Cuiwei Li: Professor and Ph.D. advisor, and a key member of the research team on specialized materials for rail transit. Her research focuses on the design, fabrication, evaluation, and application of porous ceramics, high-entropy ceramics, and ceramic matrix composites. She serves as a council member of the Ceramics Technology Division of the Chinese Ceramic Society and as a reviewer for the National Natural Science Foundation and China Government Scholarship programs.

Zhenying Huang: Professor and Ph.D. advisor. She is a council member of the Special Ceramics Division of the Chinese Ceramic Society, a council member of the Youth Working Committee of the Chinese Materials Research Society, and a council member of the Testing Technology Division of the Chinese Ceramic Society. She serves as a peer reviewer for the National Natural Science Foundation and Beijing Natural Science Foundation, and as an expert for the Ministry of Education, Ministry of Science and Technology, and Beijing Municipal Science and Technology Bureau. Her research focuses on new materials for rail transit equipment, such as pantograph sliding plates and brake disc pairs. She has been nominated for the National Top 100 Outstanding Doctoral Dissertations and has received two second prizes in provincial and ministerial-level science and technology awards.

Wenbo Yu: Professor and Ph.D. advisor, and a Young Talent (Category II) at Beijing Jiaotong University. He is a council member of the Castings Society of the Chinese Mechanical Engineering Society, an expert on the Expert Committee of the China Foundry Association, and a peer reviewer for key international cooperation projects of the National Natural Science Foundation. He also serves as a youth expert for the National Railway Group and the Beijing Municipal Science and Technology Commission. His research focuses on applied fundamental studies in integrated die-casting and surface engineering (coating and cladding) for aluminum alloy components in vehicles. He has received the Beijing Outstanding Youth Award for Rail Transit and the Zhan Tianyou Science and Technology Special Award.

Weijun Xi: He is a professor and doctoral advisor who has led over 40 national and provincial-level projects, including the 973 Program, 863 Program, National Science and Technology Major Project, and the National Key R&D Program. He has authored more than 260 papers, written two monographs, and has been awarded 16 provincial and ministerial-level prizes. Additionally, he received the Metallurgical Youth Science and Technology Award from the Chinese Society for Metals.

Zhunli Tan: Professor and Ph.D. advisor. He has led more than ten projects, including those under the 973 Program, and serves as a reviewer and responsibility expert for the National Key R&D Program. He has received the Metallurgical Award from the Chinese Society for Metals. He holds 11 authorized patents and has published over 50 papers.

Guhui Gao: Researcher and Ph.D. advisor. He has led seven national-level projects, holds 12 authorized invention patents, and has published over 60 papers. He has received a Second Prize in Metallurgical Science and Technology Progress Awards.

Lele Zhang: Professor and Ph.D. advisor; Senior Visiting Scholar at the Institute of Applied Mechanics, RWTH Aachen University (funded by the German DFG Foundation). She is also the director of the National International Science and Technology Cooperation Base for "Rail Vehicle Engineering." Her primary research areas include complex structural load analysis theory and simulation technology, passive safety structural design and assessment, and mechanical structure safety theory and engineering applications. She has been invited to give seven presentations at major conferences and high-level meetings in her research field.

Geng Chen: Professor and Ph.D. advisor. His research focuses on lightweight design of spacecraft structures, integrated design of structures and materials, and structural health monitoring of vehicles. He has received honors including the Excellence 100 Talents Program from Beijing Jiaotong University and Outstanding Doctoral Graduate from RWTH Aachen University.

Lijun Diao: Professor and Ph.D. advisor, Director of the Key Laboratory for Multi-source Power Systems of Vehicle Equipment under the Ministry of Education. He is a Fellow of the IET, a Senior Member of IEEE and the Chinese Electrical Engineering Society, and serves as a committee member and Deputy Secretary-General of the Electrical Engineering Society's Rail Transit Electrical Equipment Technology Committee. He has received the 15th Zhan Tianyou Railway Science and Technology Youth Award, the Beijing Jiaotong University "May Fourth Medal," and is recognized under the "Youth Talent Program." He has also been awarded two provincial and ministerial-level science and technology prizes.

Zhigang Liu: Professor and Ph.D. advisor, Director of the Beijing Rail Transit Electrical Engineering Technology Research Center, and Deputy Director of the China Institute of Energy and Transportation Integrated Development. He is a member of the National Engineering Professional Degree Graduate Education Advisory Committee under the Ministry of Education. He also serves as the Deputy Director of the Rail Transit Electrical Equipment Technology Committee of the Chinese Electrical Engineering Society and the Vice Chairman of the Beijing Electrical Engineering Society. He has received the State Council Special Allowance and the 2016 Mao Yisheng Railway Science and Technology Award.

Lide Wang: Professor and Ph.D. advisor. His research focuses on control, fault diagnosis, and health management of electric traction systems. He has received the

Zhan Tianyou Railway Science and Technology Award and a Second Prize in Railway Science and Technology.

Jian Wu: Professor and Ph.D. advisor, specializing in new energy applications technology for rail transit. He has led the development of relevant national and industry standards in the field of new energy for rail transit.

Zhongping Yang: Professor and Ph.D. advisor, specializing in electrical traction and drive technology, energy-saving technology, and wireless power transfer technology in the field of rail transit.

Liwei Zhang: Professor and Ph.D. advisor. His research areas include electrical control systems and wireless charging technology for rail transit and new energy vehicles, new energy storage and conversion technologies, magnetic levitation control technology, and the vehicle operation.

Weige Zhang: Professor and Ph.D. advisor, Director of the New Energy Research Institute and the Battery Testing Laboratory at Beijing Jiaotong University. His research focuses on optimizing charging for energy storage batteries, parameter identification and health assessment, and key technologies for multi-energy coupled rail transit power systems.

Ⅳ. Talent Development Goals and Quality in the Subject

1. Development Goals

1. Develop a solid understanding of Marxist basic theory, support the party's fundamental line, be patriotic, abide by laws and regulations, respect science, and possess a scientific spirit of seeking truth from facts. Cultivate a strong sense of social responsibility, a spirit of dedication, rigorous academic style, good academic ethics, and scholarly refinement.

2. Acquire a broad and solid foundation in theoretical knowledge and specialized expertise within the field of vehicle operation engineering, and stay informed about the latest developments and trends in the subject.

3. Develop the ability to independently conduct scientific research, engage in innovative thinking and research within their field, and achieve innovative results.

4. Cultivate a broad international perspective and the ability to communicate, compete, and cooperate in a cross-cultural environment.

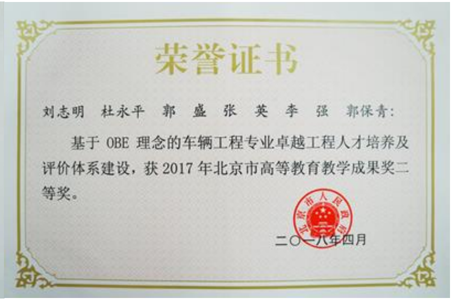
5. Be capable of working in higher education institutions, research departments, and high-tech enterprises, engaging in teaching, research, technology development, and management in the field of vehicle opreration engineering.

2. Quality of Training

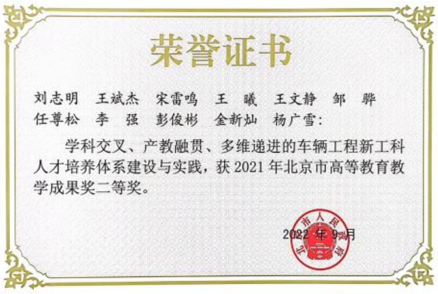
The program has been approved as a "National Engineering Professional Degree

Graduate Joint Training Demonstration Base" by the National Engineering Professional Degree Graduate Education Advisory Committee, specifically the Beijing Jiaotong University - CRRC Qingdao Sifang Rail Vehicle Engineering Professional Degree Graduate Joint Training Base.

It has also received the First Prize and Second Prize in the 2018 Beijing Higher Education Teaching Achievement Awards.



In 2021, it received the First Prize and Second Prize in the Beijing Higher Education Teaching Achievement Awards.



In 2022, it was awarded the First Prize and Second Prize in the National Teaching Achievement Awards.

V. Research Level and Subject Platforms

1. Research Level

1.1 Safety Theory and Technology of Vehicles

Significant progress has been made in the research on the reliability of rail vehicle structures, with a series of important innovative results achieved. The reliability of fatigue in key structures of new rail vehicles, including all domestic high-speed trains and approximately 90% of newly introduced rail vehicles, has been tested and evaluated. This includes several hundred tests covering the “Harmony” trains at speeds of 250-350 km/h and the “Fuxing” trains at 350 km/h, as well as key components of heavy-load trains.

The establishment of a technology system for evaluating the reliability of critical rail vehicle structures, methods for creating complex structural load spectra, and a technology system for enhancing the reliability of rail vehicle structures have been completed. This has led to a comprehensive engineering application system.

These advancements have supported the widespread application of structural reliability assessment technology in the rail transit industry, playing a crucial role in the independent innovation of rail vehicles, improving product quality, and ensuring operational safety.

1.2 Detection and Control of Vehicles and Infrastructure

Achieved a series of leading innovations in rail transit safety perception technology, with related equipment widely applied in the industry, improving safety levels and upgrading the industry chain.

Proposed an internationally pioneering technical framework for vehicle-ground collaborative perception and remote observation systems in rail transit, overcoming core algorithm and key technology challenges in onboard autonomous perception and wayside auxiliary perception. Developed the world's first high-safety-level rail transit clearance perception and remote observation system, achieving high reliability, real-time performance, and accuracy in detecting obstacles during train operation with a safety level of SIL4. This technology has been implemented in Beijing Metro, Hong Kong Metro, China National Railway Group's Shanghai and Lanzhou bureaus, and the Shuohuang heavy-load railway, promoting the upgrade of the entire rail transit industry chain.

Developed online monitoring technology and equipment for internal defects in seamless rails and switch points based on ultrasonic guided waves, overcoming challenges such as weak signal extraction, modal separation, and defect localization under complex background noise, with technology reaching international advanced levels. This equipment has been promoted in high-speed rail and heavy-load railways, enhancing operational safety.

Addressed the global challenge of monitoring locking temperature and temperature stress in seamless rails with research on online monitoring technology based on nonlinear ultrasonic guided waves. Systematically proposed theories and methods for monitoring seamless rail locking temperature using nonlinear ultrasonic guided waves, which are significant for temperature stress monitoring in seamless rails.

Developed technology for detecting full-section deformation and surface defects in tunnels, solving issues related to dynamic acquisition of three-dimensional clearance dimensions and surface images, vibration compensation, deformation analysis, and defect intelligent recognition.

Researched a comprehensive diagnostic decision model for heavy-load railway freight car status, proposing nonlinear Wiener models and mixed effects for predicting failure patterns and remaining life of key components. Developed diagnostic and evaluation methods based on gray theory and fuzzy evaluation for freight car health status. Established a dynamic maintenance model for key components, facilitating the transition from "scheduled maintenance" to "condition-based maintenance" for heavy-load railway freight cars in the National Energy Group, reducing single-car lifecycle maintenance costs by at least 20%.

1.3 Operating Environments for Vehicles and Advanced Power Technologies

The research team at the Advanced Power Technology Institute conducts its work based on the scientific platform of the Beijing Key Laboratory of New Energy Vehicle Powertrain Technology. The laboratory focuses on national strategies such as "Dual Carbon" and "Space Strategy," aligning with modern transportation development needs. The research primarily centers on smart vehicles and advanced power technologies, covering areas such as green energy, advanced power, intelligent vehicles, and aerospace propulsion.

The research has developed a battery performance evaluation method based on an empirical model, achieving real-time and accurate estimation of battery performance. This includes a battery state of charge estimation method based on a fused Kalman observer and a battery health state estimation method based on particle filtering. The team has also proposed solutions for the core components, stacks, and full-scenario applications of fuel cell engines, helping to address industry challenges such as material and component bottlenecks, poor environmental adaptability, and short life cycles in fuel cell passenger cars.

Long-term in-depth studies have been conducted on high-pressure common rail fuel systems, high-pressure fuel jet atomization processes, and combustion systems in diesel engines of armored vehicles. These studies have revealed the mechanisms of fuel atomization, rapid mixing, and combustion in high-power density diesel engines, leading to the establishment of the first domestic predictive design technology system for high-power diesel engine combustion systems. The combustion mechanisms that cause severe performance degradation in armored vehicle diesel engines in high-altitude environments have also been identified.

Fundamental research on laminar and turbulent combustion characteristics of gaseous fuels has been carried out, providing a theoretical basis for efficient and clean combustion in gaseous fuel power systems. The team has uncovered the mechanisms affecting laminar flame speeds in various gas mixture fuels, proposed evaluation methods for laminar premixed flame instability, and developed an analysis method for turbulent premixed flame propagation characteristics based on statistical theory. Additionally, they have proposed a nonlinear dynamic analysis method for combustion stability in natural gas engines.

Internationally, the team achieved the first 3D simulation of ADN thruster atomization and catalytic combustion processes, advancing China's space non-toxic propulsion technology to international levels. They also realized 3D dynamic simulation analysis of ultra-high-pressure cold gas micropropulsion systems for the first time and established a solid-fuel micro-thruster combustion model, contributing to the development of satellite propulsion systems.

The team developed an energy feedback-based power supply system for urban rail transit, achieving functions such as energy-efficient train operation, power factor compensation, and catenary de-icing. Several core technologies have reached leading levels both domestically and internationally. Research results have been applied to 18 urban rail lines in cities like Beijing and Shenzhen.

The team has mastered the core technology of a multi-source power drive system for vehicle equipment with 100% independent intellectual property rights. This technology has been successfully applied to hybrid electric trains, light rail vehicles, subways, and shunting locomotives, with achievements on multiple domestic operational lines that have gained widespread industry recognition.

Research has also been conducted on magnetic levitation train suspension and drive control technology, electromagnetic noise suppression technology for medium-speed maglev trains, and carbon fiber car body grounding and electromagnetic compatibility technology. They developed urban rail inductive power transfer technology, achieving a digital design, simulation, and evaluation platform for high-speed train auxiliary power systems. Additionally, the team worked on the multi-power simulation modeling technology for modern road electric trains, vehicle power operation stability control technology, and train tracking control and self-guiding technology.

They proposed a self-adaptive online estimation method for battery SOX (SOC, SOP, SOH) status in complex onboard environments and an online identification method for time-domain optimal battery simulation model parameters. The team established an online adaptive estimation framework for battery pack SOX status, enabling accurate estimation of battery system status throughout its lifecycle. Battery management systems embedded with online adaptive SOX estimation methods have been successfully integrated into high-safety, high-specific-energy battery systems.

The team systematically solved key technological innovation and verification challenges across the entire process of energy storage in rail transit, addressing major scientific issues such as the supply and allocation modes of various combined energy storage systems in rail transit, and improving overall efficiency and performance. The research outcomes have been applied to the Fuxing bullet train, the Beijing-Zhangjiakou high-speed railway's intelligent bullet trains, and dual-source hybrid locomotives.

They were the first in China to develop a supercapacitor energy storage system for urban rail ground use, completing actual line network operation tests. The project's results have been successively applied to Beijing Metro Line 8 and Qingdao Metro. The team undertook a sub-project of the national "13th Five-Year Plan" key research and development program, successfully developing China's first MW-level urban rail ground-based supercapacitor/lithium battery hybrid energy storage system. Demonstration operations at the Liyuan Station on the Batong Line indicated significant energy-saving effects.

1.4 New Materials Science and Technology for Transportation Vehicles

The research team specializing in special materials for rail transit is guided by the national strategy of building a strong transportation network, closely aligned with the significant needs of China's rail transit industry. They conduct in-depth and systematic research on the development and application of key materials and components for rail transit. Their work includes fundamental theoretical studies and key applied technology research in areas such as the design and preparation methods of advanced steel materials, strengthening and toughening mechanisms, failure mechanisms, forming techniques, and surface treatment of components. The team boasts a well-rounded and distinctive research platform for material development, making them a key research group in the field of steel materials for rail transit in China.

In the development of bainitic steel rails and wheels, the team has achieved internationally advanced levels, establishing a new Mn-Si-Cr-Mo low-alloy bainitic wheel-rail prototype steel system. They have developed stabilization technology for the microstructure and properties of low-cost Mn-series bainitic steel, significantly advancing the research and application of bainitic steel rails and wheels. The newly developed bainitic wheels have been applied to actual railway lines, providing strong technical support for the future development of high-speed and heavy-haul railways.

In the area of metal composite materials, the team has developed stainless steel/carbon steel composites and aluminum-copper composites for railway use, achieving lightweight structures with excellent thermal conductivity, which have been applied in automotive engines. The team also leads domestically in the research of military gear steels, the hydrogen embrittlement behavior of third-generation high-strength medium-manganese steels for automobiles, low-cost high-strength steel for automotive forgings, and high-strength steel for fasteners.

2. Research Platforms

2.1 The Key Laboratory of Multi-source Power Systems for Transport Equipment of Ministry of Education

The Key Laboratory of Multi-source Power Systems for Transport Equipment of the Ministry of Education focuses on the advanced energy and power field within the subject of Vehicle Operation Engineering. The laboratory is established at the School of Electrical Engineering, Beijing Jiaotong University. It addresses critical and cutting-edge scientific issues related to highly integrated hybrid power supply systems, including strong coupling reconstruction of multi-source power systems, multi-constraint control, high-efficiency and high-safety power storage and management, and adaptability to diverse application scenarios. The laboratory aims to provide systematic foundational theories, key technologies, and talent support for the leapfrog development of power systems for transport equipment in China.

Officially approved by the Department of Science and Technology and Information of the Ministry of Education, the laboratory held its Construction Plan Expert Demonstration Meeting and the first Academic Committee Meeting in Beijing on April 11, 2023. The main research directions include drive motor design and collaborative optimization, multi-source power drive technology, energy storage technology, and power system RAMSI technology. Currently, the laboratory hosts several technical demonstration and research platforms, such as a high-power multi-energy coupled energy storage system research platform, servo drag test system, self-developed high-speed permanent magnet multi-phase fault-tolerant servo motor drag test bench, traction motor bearing test bench, high-power electric drive system test platform, multi-source power traction converter test platform, hardware-in-the-loop and digital simulation platform, energy storage system testing and evaluation laboratory platform, on-the-move safety monitoring and early warning laboratory platform, transmission system vibration detection platform, and intelligent operation and maintenance management platform.

2.2 Engineering Research Center for Reliability and Testing Technology of Rail Transit Equipment, Ministry of Education

The Engineering Research Center for Reliability and Testing Technology of Rail Transit Equipment, under the Ministry of Education, was officially approved for construction on October 12, 2007. The center is based at Beijing Jiaotong University and was established in collaboration with Datong Electric Locomotive Co., Ltd., Changchun Railway Vehicles Co., Ltd., CRRC Qingdao Sifang Co., Ltd., and Qiqihar Railway Rolling Stock Co., Ltd. The center is a comprehensive research institution that integrates technology development, experimental research, technical consultation, and service. Its functions include the development of core technologies, technical support and consultation for major projects, engineering monitoring, and testing services. Through the development of new technologies and the transformation of research results, the center aims to lead in the reliability and testing technology within the rail transit equipment industry.

The center has four main research directions: structural reliability assessment and design, testing technology and equipment, development and application of key components, and vibration and noise detection and control. Closely aligned with national and industry strategic needs, and in line with the university's double first-class construction goals, the center focuses on critical core technologies essential for the development of rail transit, continually enhancing its ability to serve the industry and society.

The center has a relatively stable research team of 55 members, primarily consisting of faculty and laboratory technicians from the School of Mechanical, Electronic, and Control Engineering at Beijing Jiaotong University. Among them, 20 hold senior titles, 18 are associate professors, and 61.5% of the research team members hold doctoral degrees. The center has cultivated a high-level scientific team in the field of structural reliability and operational testing of rail vehicles through a combination of internal training and external recruitment.

The center also hosts one key innovation team in critical areas from the Ministry of Science and Technology and one innovation team from the Ministry of Education. The team includes one academician from the Chinese Academy of Engineering, four recipients of the Ministry of Education’s New Century Talent Support Program, one recipient of the Mao Yisheng Railway Science and Technology Award, two recipients of the Zhan Tianyou Achievement Award, two recipients of the Zhan Tianyou Contribution Award, two recipients of the Zhan Tianyou Youth Award, two experts who receive special government allowances, one Beijing Teaching Master, and one Beijing Science and Technology Star.

2.3 Frontier Science Center for Smart High-Speed Rail Systems

The Frontier Science Center for Smart High-Speed Rail Systems, established at Beijing Jiaotong University, was officially approved for construction by the Ministry of Education on December 31, 2020. It is the only frontier science center in the field of rail transit and serves as a crucial initiative in implementing the Ministry of Education's "Everest Plan for Basic Research in Higher Education." The center focuses on solving global challenges in three main areas: autonomous train operation, seamless passenger services, and high-speed rail health management. Its mission is to meet the strategic needs of national priorities, such as building a strong transportation network, by driving tasks with a multidisciplinary team of top-tier researchers. The center aims to explore and lead in foundational theories and cutting-edge technologies within the smart high-speed rail domain, achieving round-the-clock, fully autonomous train operation, intelligent door-to-door passenger services, and the development of digital twin models for critical components like train bogies and tracks. These innovations are intended to ensure real-time maintenance and address the challenges facing the next generation of rail transit systems in China, providing theoretical, technological, and talent support for the development of smart high-speed rail systems, thereby solidifying China's status as a global leader in this field.

2.4 Key Laboratory of High-Speed EMU Structural Reliability, Railway Industry

The Key Laboratory of High-Speed EMU Structural Reliability, recognized as a Railway Industry Technology Innovation Base by the National Railway Administration, is led by Professor Qiang Li from the School of Mechanical, Electronic, and Control Engineering at Beijing Jiaotong University. The laboratory is co-established with CRRC Qingdao Sifang Co., Ltd., CRRC Changchun Railway Vehicles Co., Ltd., and CRRC Tangshan Co., Ltd. The laboratory has long been engaged in the research of structural reliability in rail vehicles, making significant advancements in areas such as the establishment of load spectra for high-speed trains, heavy-haul freight cars, accelerated passenger trains, and intercity rail vehicles, as well as the development of theories and evaluation systems for the structural reliability of rail transit equipment, line testing, fatigue testing, and data platforms for structural reliability. These achievements place the laboratory at the forefront of the industry in China and at an advanced level internationally, making it a key research base for the structural reliability of high-speed EMUs.

Focusing on the specific needs of China's high-speed train development, the laboratory concentrates on three main research areas: the study of load spectra for high-speed train structures, the design and evaluation of structural reliability for key high-speed train components, and the research of health monitoring technologies and methods for these critical structures. The laboratory is dedicated to developing the theories and methods that ensure the operational reliability of high-speed train structures, safeguarding the safe operation of China's high-speed rail network. The laboratory also emphasizes the integration of scientific innovation with talent cultivation, targeting the rapid development and significant needs of the transportation sector. By promoting interdisciplinary studies, innovating talent cultivation models, and strengthening the development of transportation-specific programs, the laboratory aims to build a special zone for cultivating top-tier, innovative talents. The establishment of the laboratory is of great significance in ensuring the operational safety of high-speed rail mobile equipment and the orderly operation of the high-speed rail network, providing essential theoretical and talent support for the development of high-speed rail in China. In the future, the laboratory will further research the universal load spectra under specific operational environments to achieve the forward-looking design of structural reliability for rail vehicles.

2.5 Rail Transit Special Materials Research Team

The Rail Transit Special Materials Research Team has co-established the provincial-level platform "Beijing Laboratory for Modern Traffic Metal Materials and Processing Technology" with the University of Science and Technology Beijing, among other institutions. In 2022, the team was approved to construct the Hebei Provincial Rail Transit New Materials Industrialization Maturity Base, where a subway pantograph slider production, assembly, and inspection line has already been completed as a demonstration of industrial manufacturing. In 2023, the team received the Hebei Provincial CMA qualification certificate, authorizing the inspection and testing of high-speed rail and subway pantograph sliders and contact wires.

Ⅵ. Domestic and International Influence of the Subject, Social Services, and Outstanding Achievements

The Intelligent Detection Technology Research Institute for Rail Transit focuses on the fundamental theories and key technologies for the safety state perception of rail transit vehicles, roads, and environments. They have achieved innovative results in intelligent perception of train operating environments, service state perception of line infrastructure, fault identification, and condition repair of rail vehicles. They have led two national key R&D projects, one key project of the National Natural Science Foundation, and three key projects of the China Railway Corporation. They have won two first prizes from the China Railway Society and one second prize for scientific and technological progress from Beijing.

The Rail Vehicle Structure Reliability Research Team has long been engaged in the reliability research of rail vehicle structures. With strong support from the country, the Ministry of Science and Technology, and the China Railway Corporation, they have closely cooperated with rail vehicle manufacturing enterprises to evaluate the structural reliability of all high-speed EMUs and over 90% of new rail vehicles in China. They have achieved a series of important innovative results through continuous efforts, becoming the main research base for the structural reliability of high-speed EMUs in China. Their work has played a crucial role in independent innovation, improving product quality, and ensuring the safe operation of rail vehicles.

They have innovatively proposed the theory of consistent load spectrum for key structures of rail vehicles, solving the problem of establishing load spectra for complex structures. The load spectra being established play an important role in comprehensively solving the structural reliability issues of existing rail transit equipment under complex operating conditions.

Their achievements have been applied to the “Fuxing” series of Chinese standard EMUs, which will be promoted in Russia, Thailand, Indonesia, and exported to Brazil and Argentina for urban rail vehicles. This provides important theoretical and technical support for the development, safe operation, and “going global” strategy of China high-speed rail and urban rail. They have practiced the collaborative innovation model of “government-industry-university-research-application”, promoting the rapid development of high-speed EMUs, heavy-duty trains, and urban rail vehicles.

The Advanced Power Technology Research Institute team has closely cooperated with many universities and enterprises, including Tsinghua University, Beihang University, Jilin University, Chery Automobile Co., Ltd., BAIC New Energy Co., Ltd., Zhengzhou Yutong Co., Ltd., Beijing Jingwei Hengrun Co., Ltd., Weichai Power Group, China North Industries Group 701 Institute, and Inner Mongolia First Machinery Group Co., Ltd., to jointly develop and tackle key technologies in related fields.

The “Vehicle Energy Management Control System” developed in cooperation with enterprises has been widely applied to various models of new energy vehicles of BAIC New Energy Co., Ltd., covering Beijing, Jiangsu, Zhejiang, and other provinces and cities. They have established the “New Energy Vehicle Technology Industry-University-Research Joint Graduate Training Base” with BAIC New Energy Co., Ltd., comprehensively training scientific research, management, and service talents to adapt to the development of new energy vehicles based on industry needs.

The research team has provided technical support to enterprises such as BAIC New Energy Co., Ltd. and BAIC Foton Co., Ltd. in new drive technology, powertrain control technology, and hydrogen fuel cell system safety monitoring for new energy vehicles. They solve engineering and technological problems through the industry-university-research joint model.

The Beijing Key Laboratory of New Energy Vehicle Powertrain Technology has strengthened team building and talent training, emphasizing the role of young scientific and technological talents in innovation projects and cultivating outstanding young scientific research backbones. The laboratory focuses on open communication, setting up open topics, and strengthening the training of graduate students to improve their scientific research and comprehensive quality.

The Rail Transit Special Materials Research Team has originally invented high-performance MCC sliding plates for high-speed EMUs, completing 600,000 kilometers of cumulative loading and passenger operation assessment at speeds of 300 km/h and below on high-speed passenger lines such as the Beijing-Guangzhou, Beijing-Shanghai, and Xiang-Gui lines. The product's technical indicators have been included in the standard technical documents of the China Railway Corporation and have obtained CRCC certification for Chinese railway products, breaking the long-term technical monopoly of foreign carbon-based sliding plates and generating significant social benefits.

The Rail Transit Metal Materials Research Institute team has developed bainitic steel rails, turnouts, and wheels, which have been promoted and applied in 18 railway bureau companies nationwide. Currently, they are one of the key products promoted by the China Railway Corporation. The 1380 MPa grade bainitic steel rails and turnouts developed in cooperation with Baogang Group have been successfully trial-laid on heavy-haul railways such as the Daqin and Houyue lines, solving the technical problem of severe side wear and low lifespan of small-radius curve rails. They participated in the formulation of the "Interim Technical Conditions for 1380 MPa Grade Bainitic Steel Rails." Team members serve as members and deputy secretaries-general of the Special Steel Sub-Technical Committee of the National Steel Standardization Technical

Committee.

The “Rail Transport Operation Engineering” National and International Science and Technology Cooperation Base was officially approved by the Ministry of Science and Technology in February 2018 and passed the evaluation in 2020, entering the second round of construction. As a national platform, the approval and evaluation of the base mark the internationalization level and talent training quality of the school and college. In 2020, the base applied for the National Scholarship Council’s innovative talent training project with the theme of “Joint Training of International High-End Innovative Talents in the Design, Manufacturing, and Operation of Next-Generation High-Speed Trains,” which successfully commenced operations in 2022. Since the project started, it has achieved a series of outstanding results in international cooperation: leading the signing of multiple school-level agreements for talent training and scientific research cooperation between our school and five internationally renowned universities, including RWTH Aachen University in Germany; completing the signing of a dual master’s degree program agreement with KTH Royal Institute of Technology in Sweden; and successfully obtaining funding from the China-German Science Center (Chinese National Natural Science Foundation) for the fifth time for the China-German Summer School in 2020. Since its establishment, the international cooperation base has always contributed its unique strength to the internationalization and subject evaluation of the subject of vehicle operation engineering.