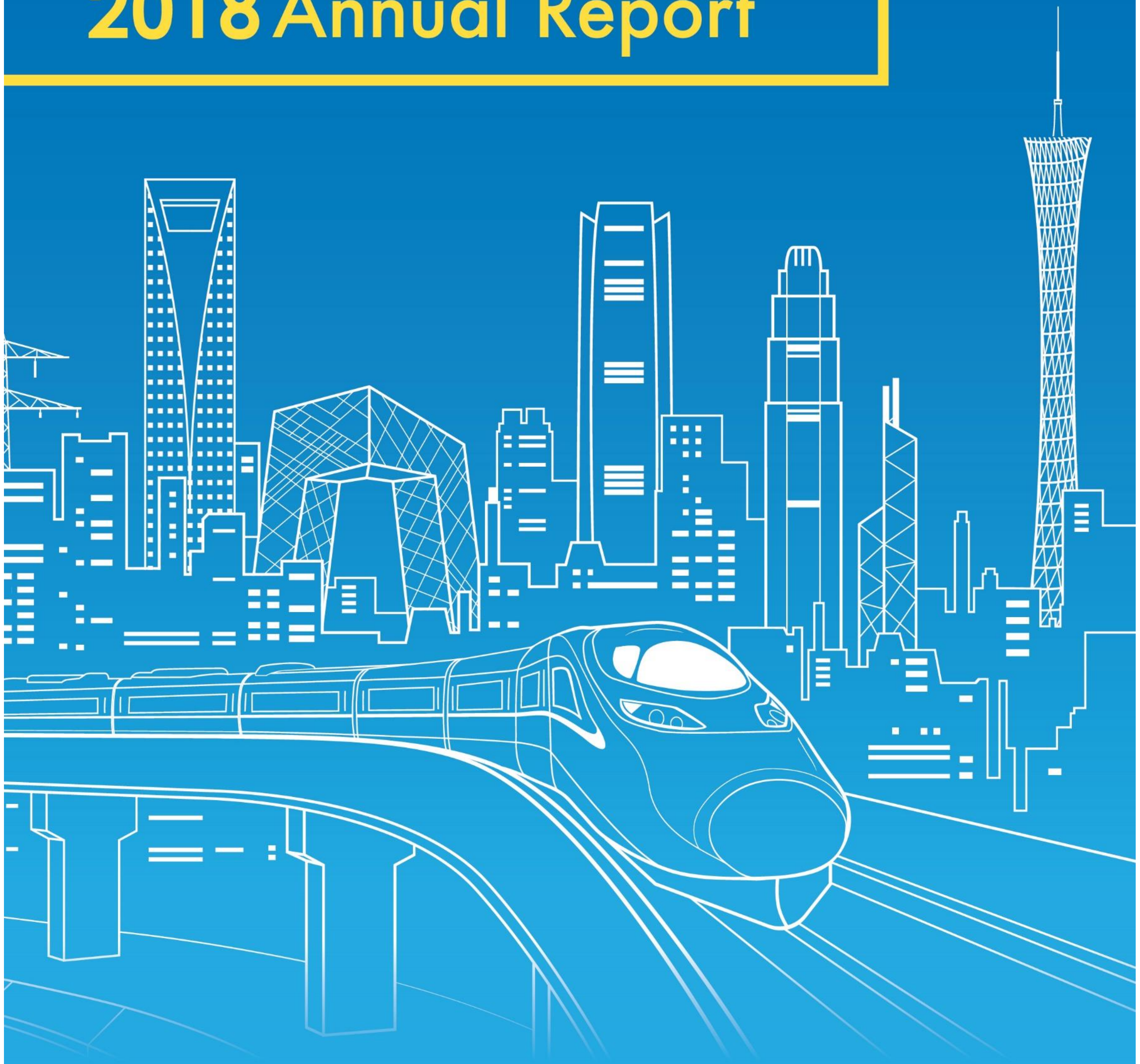
CNERC-Rail
2018 Annual Report



THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

CNERC-Rail
HK

National Rail Transit Electrification and Automation Engineering Technology Research Center (Hong Kong Branch)
國家軌道交通電氣化與自動化工程技術研究中心(香港分中心)

CONTENTS

Highlights of the Year

May, *Singapore*

Memorandum of Understanding was signed with SMRT Corporation Ltd.

June, *Hong Kong, China*

Center's Director Prof. Yi-Qing Ni was invited to attend the Luncheon hosted by the Chief Executive of the HKSAR at Government House.

October, *Shenzhen, China*

Signing Ceremony of Guangdong-Hong Kong-Macau Greater Bay Area Modern Rail Transit Collaborative Innovation Center was held.

October, *Shenzhen, China*

CNERC-Rail co-organized the 2nd Guangdong-Hong Kong-Macau Greater Bay Area Advanced Rail Transit Summit.

November, *Qingdao, China*

CNERC-Rail received Outstanding Paper Award and Honorable Paper Award in the 2nd International Workshop on Structural Health Monitoring for Railway System.

November, *Tainan, China*

CNERC-Rail co-organized the Forum on “Era of Intelligent and Robust Railway” with Taiwan Cheng Kung University.

November, *Beijing, China*

CNERC-Rail co-organized the Opening Ceremony of High-Speed Railway Committee of China Railway Society (CRS) and the 2nd Forum on Smart Railway Technology.

December, *Hong Kong, China*

Visit by delegation from National Rail Transit Electrification and Automation Engineering Technology Research Center of Southwest Jiaotong University to take part in the annual meeting.

Director's Foreword

This year marks the 40th anniversary of the implementation of the reform and the confident "opening up" policies of China. With the commissioning of the Hong Kong Section of the Guangzhou-Shenzhen-Hong Kong High-Speed Rail on 22 September 2018, Hong Kong has now become physically more closely connected with the major Mainland cities, in particular, the Greater Bay Area cities. President Xi pointed out that Hong Kong, with its solid scientific and technological experience, can provide a firm foundation in an ever developing pool of high quality technological talent, and hence is an important force in the implementation of the Chinese nation's innovation-driven development strategy. In so doing, he also supports the development of Hong Kong as a parallel international I&T hub. In consequence, Hong Kong will continue to capitalize on the opportunities arising from the Guangdong-Hong Kong-Macau Greater Bay Area (Greater Bay Area) development and actively participate in the Belt and Road (B&R) Initiative.

During 2018, the Hong Kong Branch of the National Rail Transit Electrification and Automation Engineering Technology Research Center (CNERC-Rail) has made substantial progress in many areas including R&D, comprehensive collaboration with many top-tier universities and, importantly with high-speed rail (HSR) manufacturing enterprises worldwide. The constant focus of the work of the Center amounts to the development and introduction of an ensured guarantee of railway safety, based on the clinical improvement of those challenging problems currently depressing the railway industry. The achievements of 2018 provide a firm base upon which the Center will further continue to: (i) engage in enhancing the ride comfort and reliability of high-speed trains; and (ii) develop the smart aspects of HSR by means of advanced technologies, all with the solid aims of both contributing to the strength of Hong Kong and, obviously the overall comfort and safety of passengers. According to the study on "The Second Railway Development Strategy" issued by the Transport Department, the Hong Kong SAR Government proposed a new plan: "Railway Development Strategy 2014". The Center is honored to participate in the plan and carry out research work accordingly.

We are happy to take this opportunity, to express our gratitude to the Ministry of Science and Technology of China, the Innovation and Technology Commission of The Government of the Hong Kong Special Administrative Region, and The Hong Kong Polytechnic University for their generous funding and steadfast support. We are confident that CNERC-Rail will achieve even greater success together with all the concerted efforts of stakeholders, partners, and friends.

Professor Yi-Qing Ni
Director of CNERC-Rail
February 2019

1. Overview

The 26-km-long Hong Kong Section of the Guangzhou-Shenzhen-Hong Kong high-speed railway has been commissioned since 22 September 2018. This connects Hong Kong to the national high-speed rail network and further enhances Hong Kong to be the southern gateway of China. The mileage of the China high-speed rail network has now become the longest in the world and is to be expanded to 30,000km by 2020. The China high-speed rail network, including the Guangzhou-Shenzhen-Hong Kong high-speed rail line, is passenger-oriented and has a positive impact on public life in the following aspects: (i) increasing travel efficiency and ride comfort and promoting prosperity as well as living quality of both Hong Kong and Mainland China; (ii) stimulating economy development of the region covered by the high-speed rail network; (iii) reducing the travel time between Hong Kong and the major cities of Mainland China. For instance, the travel time from Hong Kong to Shanghai and Beijing will be greatly shortened to 8 hours and 9 hours respectively; and (iv) enhancing synergies between regions and creating more opportunities so as to meet the current strategic demand for national development.

In particular, the Ministry of Science and Technology and the Ministry of Finance of the China have released the announcement in May 2018 to support Hong Kong to be an international innovation and technology hub. The announcement highlights that universities and research institutions in Hong Kong can apply for research funds from the Ministry of Science and Technology directly to implement the interflow of research funds between the Mainland and Hong Kong. CNERC-Rail has successfully applied for the Hong Kong, Macau, and Taiwan Science and Technology Innovation Cooperation Key Projects and has received 1,000,000 CNY funding. The Center has been conducting the research on "Condition Monitoring and Intelligent Technology for Operation and Maintenance Decision of High-Speed Railway" under this funding scheme. Since the Central Government is enlarging support regarding the science and technological development of Hong Kong, the Center will keep focusing on the research in the rail transit area and dedicate to technological innovation and knowledge transfer contributing to the further development of China's high-speed rail.

With the above missions in mind, the Center has made substantial progress in conducting the related research and technology transfer during 2018. Over the past period, CNERC-Rail has established collaboration with many top-tier universities and high-speed rail manufacturing enterprises worldwide. The synergy is of great importance to both scientific research and engineering practice.

CNECR-Rail has been seeking various forms of collaboration and actively participating in academic activities. In 2018, the Center has co-organized international conferences and forums, and Center members have chaired special sessions in multiple international conferences. Multi-hierarchical business trips and site-visits have been conducted during 2018 for both technical exchange and potential collaborations (refer to Chapter 5). The experience of international communication provides solid support for the Center to carry out research development and to conduct various engineering projects in the railway area. The Center keeps deepening collaboration with top-tier universities, enterprises, and research institutes in the field of rail engineering. For instance, Memorandums of Understanding (MoU) have been signed with SMRT Corporation Ltd. (SMRT). Furthermore, the Center has built up long-term partnership with China Academy of Railway Sciences (refer to Chapter 2).

CNERC-Rail has conducted multiple R&D activities during 2018 and made practical progress in the field of laboratory development, topic-specific research, technology transfer, industrial cooperation, academic exchanges, experimental platform developments, and the further establishment and development of new research teams.

CNERC-Rail's Latest Research Developments

The three research laboratories of the Center are listed as follows. Each laboratory has undertaken multiple R&D projects related to rail engineering.

1. The Research Laboratory for High-Speed Rail Traction Power System and Safety Technology;
2. The Research Laboratory for Advanced Sensing Techniques for High-Speed Rail Monitoring;
3. The Research Laboratory for Condition Monitoring and Vibration Control of High-Speed Trains.

Figure 1.1 Opening Ceremony of Establishment of CNERC

The research areas of the above laboratories have been extending to high-speed railway monitoring, control, condition assessment and energy efficiency, and particularly to areas related to operation safety and efficiency (refer to Chapter 3). To enhance the progress efficiency, CNERC-Rail's awarded funds have been allocated to procure equipment and recruit research personnel (refer to Appendix 2). The R&D achievements are presented in Chapter 3. The aim of the current research is directed towards technological challenges, especially (i) areas which threaten operation safety; and (ii) those which lower transport efficiency.

In terms of academic achievements in 2018, 63 scientific papers have been published, 6 patent applications have been accepted, in which 2 patents have been filed.

In general, CNERC-Rail has conducted a series of R&D projects and achieved fruitful outcomes in 2018. Looking forward to the future, the Center will keep focusing on becoming a world-leading smart and intelligent railway research center, and on fostering research and technical talents in the area. CNECR-Rail will be devoted to the implementation of "The Belt and Road Initiative" and the Guangdong-Hong Kong-Macau Greater Bay Area development.

2. Remarkable Collaborations

The importance of the collaborative interests indicated above, is seen, in practice, as a corner stone of the working philosophy of CNERC-Rail in 2018, and has become the obvious way forward for the development of smart high-speed rail. In recognition of this energetic sincerity, CNERC-Rail has been subsequently recommended to be responsible for handling both knowledge sharing and relevant progressive responsibilities with different partners. The signed MoU and collaborative agreements have indelibly marked the commencement of a long-term collaborative relationship.

2.1 Collaboration with SMRT Corporation Ltd. (SMRT)

Prof. Yi-Qing Ni, Director of CNERC-Rail and Mr. Yuen-Ming Liong, Head of Future Systems, SMRT signed a Memorandum of Understanding in Singapore on 30 May 2018. Both parties sealed agreements regarding research and railway technology development collaboration on metros, intercity and high-speed railways. In addition, the promotion and development of academic and technical collaboration were also positively encouraged with details to be imminently finalized. Potential collaboration includes funding application by Hong Kong's railway-related research field projects. The hosting of international academic conferences in railway-related fields by the two parties was also suggested.

Figure 2.1 PolyU and SMRT singed an MoU on collaborations

As a major mass transportation provider in Singapore, SMRT has paid a lot of efforts in the recent years for improving their service quality and reliability. In the metro line domain, SMRT has sourced globally for new technologies for the two busiest metro lines in Singapore that are the North South Line (NSL) and East West Line (EWL) in order to cope with the ever-increasing demand and new challenges. The NSL is 45km long with 26 stations from Jurong East to Marina Sooth Pier. The EWL is 57km long serving 35 stations from Paris Ris to Tuas Link.

In order to improve rolling stock and railway infrastructure maintenance and asset management effectiveness and efficiency of these two lines, SMRT has acquired the PolyU Train Track Condition Monitoring System (TTCM) after a detailed global study and comparison of existing technologies that they cannot find any with matching capability and development potential as the PolyU TTCM. The TTCM system is a member of the Smart Railway System in which the sensing infrastructure is based on the fiber Bragg grating sensing technology. Fiber Bragg grating (FBG) sensing and monitoring system is the perfect candidate for medium to large scale condition monitoring such as railway infrastructure. Based on one single technology, FBGs can be transformed into different types of transducers for measuring different parameters such as strain, temperature, pressure, displacement, electric and magnetic field, etc. and all different transducers can be interrogated with one single interrogation system. Since the entire sensing network including the sensors themselves is transmitting optical signal inside optical fibers, FBG sensing system also has the same advantages as fiber-optic communication system including long transmission distance, high signal fidelity, total immunity to electromagnetic interference, to name but a few.

The TTCM was delivered and installed by PolyU in the first quarter of 2018 which is now undergoing a calibration and testing & commissioning process. The system will be delivered to the operation department of SMRT by mid-2019. SMRT is now considering to upgrade the system function and extent by installing different types of fiber-optic sensing at the sensing network and also introduce the TTCM to the other metro lines operated by SMRT.

2.2 Guangdong-Hong Kong-Macau Greater Bay Area Modern Rail Transit Collaborative Innovation Center

In addition, The Hong Kong Polytechnic University (PolyU) "joined hands" with Shenzhen University (SZU) together with other over 10 universities and parties to set up the "Guangdong-Hong Kong-Macau Greater Bay Area Modern Rail Transit Collaborative Innovation Center (CIC)". An MoU signing ceremony was held in Shenzhen, on 12 October 2018 with all 12 partner institutions present. This particular occasion both signifies the beginning of further cohesive research and also the developmental collaboration and progressive advancement of rail engineering. It emphatically highlights the importance of building an integrated rail transit system within the "Guangdong-Hong Kong-Macau Greater Bay" (the Greater Bay) by combining the research strengths of the above collaborative parties.

The CIC is devoted to promoting the innovative technologies development in the Greater Bay area. This global innovatory platform will also promote the collaborations between universities and industries.

The educational by-products produced by the Greater Bay are expected to include the following items: (i) cooperation opportunities between universities and industries on the smart sensing and railway health monitoring; (ii) safe operation and maintenance; (iii) pre-alarm functions and the disaster resilience of rail systems; (iv) the deepening of relevant talents for the Greater Bay Area by means of associated knowledge, gained from experience of experts in rail transportation; (v) the sharing of partners education resources and personal relevant strengths; (vi) the support and promotion of technology transfer; and (vii) the industrialization of research outcomes of partners within and beyond the Greater Bay Area.

Professor Ping-Kong Alexander Wai, Vice President (Research Development) of the PolyU pointed out that leveraging the "one country, two systems" principle and the distinctive feature of internationalisation, Hong Kong has the full advantage to become an international innovation and technology hub.

PolyU has been actively participating in national research projects such as China's Lunar Exploration Programme with remarkable achievements. Recently, a First Biotechnology and Translational Medicine research platform, a Joint Center for Immunotherapy and a Supercomputer Union were established between PolyU and research institutes in the Greater Bay Area. In recognition of the past experience, it is expected that the newly founded CIC can leverage the advantages of every member and promote applications of innovative technologies into various aspects.

The CIC includes cross border universities and research institutions, indicating a strong base for diversified cooperation with fruitful inputs and possible achievements. Professor Qing-Quan Li, President of SZU, indicated that the establishment of CIC would provide a strong boost to the development of the Greater Bay. Academician of China Academy of Engineering, Professor Yan-Liang Du also remarked that the CIC integrates different rail transit needs. Thus their consolidation and the potential of further development within the Greater Bay will, by its innovatory technology contribute to giving the area a smart and modern transportation network.

The MoU was signed by Professor Ping-Kong Alexander Wai, Vice President (Research Development) of PolyU and Professor Qing-Quan Li, President of SZU as representatives from the two leading units, with over 10 partners including Sun Yat-sen University, Guangzhou University, Beihang University, Southwest Jiaotong University, University of Macau of China, Imperial College London and University of Birmingham of the United Kingdom, China Academy of Railway Sciences Corporation Ltd., the China Railway Engineering Consulting Group Corporation Ltd. and Shenzhen Guangshengang Investment Management Corporation Ltd. The MoU signing ceremony included Mr. Ju Ming, Associate Director, Department of Science and Technology, Ministry of Education and Mr. Feng Xing, Deputy Director, Department of Education, Guangdong Province who gave supportive speeches. The occasion was also well attended by various officials and leaders from industry.

Figure 2.2 Professor Ping-Kong Alexander Wai, Vice President (Research Development) of PolyU and Prof. Qing-Quan Li, President of Shenzhen University (5th & 6th from right) signed the MoU for the set-up of Guangdong-Hong Kong-Macau Greater Bay Area Modern Rail Transit Collaborative Innovation Center

Figure 2.3 The signing ceremony at Shenzhen University was well attended by officials and representatives from over 10 universities and institutions

2.3 Collaboration with China Academy of Railway Sciences (CARS)

In 2018, CNERC-Rail has established solid communication with China Academy of Railway Sciences (CARS) through R&D collaboration with two institutes of CARS: Railway Engineering Research Institute and Infrastructure Inspection Research Institute, on the development of cutting-edge technologies related to such as wheel/rail load transmission measurement, condition monitoring for railway vehicles and tracks, machine learning techniques for fault detection. In addition, we have built up long-term collaborative relationships with CARS and will jointly organize forums and international conferences, and jointly apply for research funding from the Mainland and Hong Kong. The collaboration can benefit the technology transfer of advanced rail infrastructure management.

Collaboration with Infrastructure Inspection Research Institute

In April and September, a delegation from Infrastructure Inspection Research Institute paid two visits to the Center and had technical meetings with key CNERC-Rail members. Nine research projects tackling the most challenging problems in track inspection for HSR have been launched: (i) Wheel-rail interaction force quantification based on vehicle dynamic response measurement; (ii) Track irregularity measurement using fiber optic sensors; (iii) High-frequency vehicle dynamic response monitoring based on compressed sensing; (iv) Short-pitch rail corrugation detection using deep learning and Bayesian methods; (v) Interference wave identification for early warning of seismic P-wave; (vi) Vibration component extraction from bridge dynamic response; (vii) Multi-target-based maintenance strategy for railway; (viii) Deep learning based mining method for geological radar monitoring data; and (ix) Data mining on electronic system information in HSR.

CNERC-Rail team members visited CARS in January 2019 to follow up these research projects. Generally, these collaboration projects aim to enhance accuracy and reliability of HSR track irregularity measurements, wheel impact quantifications and fault detections by advanced sensing and machine learning technologies.

Collaboration with Railway Engineering Research Institute

Since 2016, CNERC-Rail has been collaborating with Railway Engineering Research Institute, CARS on the research project titled "wheel load transmission measurement in HSR slab track based on FBG sensing technology". As stipulated by the project, CNERC-Rail has developed FBG-based embedded sensor arrays specifically designed for CRTSIII slab track. The implementation of embedded sensors as well as the setup of data acquisition system has been completed in February 2018. The Beijing-Shenyang HSR has begun trial operation since March 2018. The strain responses of track slab and basement to wheel load excitations are to be collected by the embedded sensors.

Figure 2.4 Installation of embedded GFRP-FBG sensor array

2.4 Collaboration with National Maglev Transportation Engineering R&D Center in Tongji University

On 10 October 2018, Prof. Yi-Qing Ni, Director of CNERC-Rail, and Dr. Su-Mei Wang paid an official visit to National Maglev Transportation Engineering R&D Center (NMTC) in Tongji University for a technical exchange with the experts of NMTC. The Director of NMTC, Prof. Xiao-Hong Chen introduced the background and general interests of NMTC. The Deputy Director Prof. Guo-Bin Lin reported on the development of the maglev train and maglev technology M3 from American. In addition, Dr. Hong-Liang Pan from NMTC gave an informative presentation detailing both the present maglev systems and the current research in China and also abroad. Details of the NMTC projects were also introduced. Prof. Ni, in turn, introduced the development of CNERC-Rail and CNERC-Rail's main research objectives and projects, especially the FBG sensor technology-based heath monitoring on high-speed railway. He also expressed his expectation to conduct collaborative researches on track-train systems of maglev transportation.

After the meeting, Dr. Pan introduced the maglev's high-speed and low-speed test bases to Prof. Ni and Dr. Wang. Several potential cooperative projects have been launched, which include (i) the establishment of a maglev train-rail-bridge model and experimental study; (ii) development of monitoring technology for the maglev train-rail-control system based on FBG sensor technology; (iii) the noise model and noise control for maglev systems; and (iv) modeling and optimization of control system for maglev trains.

Figure 2.5 Visit to National Maglev Transportation Engineering R&D Center

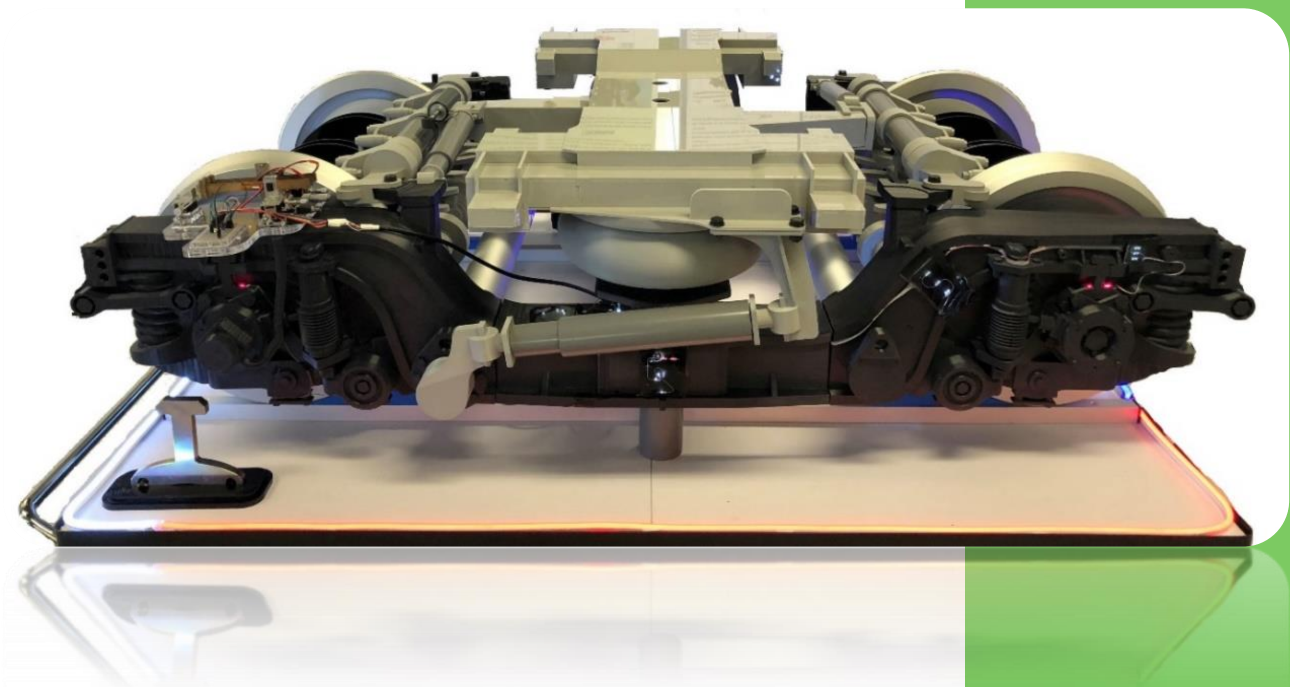
2.5 Collaboration with China Railway Guangzhou Group Co., Ltd.

In 2018, CNERC-Rail cooperated with CSRD and China Railway Guangzhou Group Co., Ltd. (hereinafter referred to as CR Guangzhou) on a newly proposed research project "Life-cycle management for HSR infrastructure based on BIM and SHM techniques". This project aims to conduct structural health monitoring for HSR critical infrastructure (e.g. bridges, tunnels and stations that raise challenges in construction, railway turnouts, slab tracks, etc.), to introduce the life-cycle concept in rail infrastructure management. The whole system adopts numerous cutting-edge techniques, including BIM management, machine learning theory, big data theory, virtual reality, augmented reality.

Since August 2018, up to five meetings have been held by the three parties to discuss the implementation of this project. Relevant institutes, including design and construction companies also attended some technical meetings. Based on these discussions, a consensus was made to implement the proposed system on Guangzhou-Shanwei HSR which is a new HSR that will be constructed in the coming years (led by CR Guangzhou). CNERC-Rail has currently completed the design of the monitoring program for the main infrastructures of the HSR line. In 2019, CNERC-Rail and CSRD will focus on the development of the proposed system by integrating the aforementioned cutting-edge technologies. Meanwhile, CNERC will keep contact with CR Guangzhou and design and construction companies in regard to system implementation. In summary, this project aims to promote a new era of the further development of structural health monitoring technology in the railway industry.

Figure 2.6 CNERC-Rail is meeting with CR Guangzhou

3. R&D Projects



In 2018, CNERC - Rail has focused mainly on the following research areas

Target-Oriented Structural Health Monitoring Systems

Safety and Reliability Assessment by Data Mining

Vibration Mitigation and Vibration Energy Harvesting

Other Innovation Research Projects

3.1 Target-Oriented Structural Health Monitoring Systems

3.1.1 Train Axles Crack Detection by Utilizing Guided Waves

3.1.2 The Effects of the Application of Ultrasonic Guided Waves in Structural Health Monitoring of High-Speed Railways

3.1.3 Incipient Damage Detection by Employing of Nonlinear Guided Waves Excited by Magetostrictive Transducers

3.1.4 HSR Track Slab Condition Monitoring and Load Transmission Evaluation Enabled by the Use of Embedded FBG Sensors

3.1.5 Real-Time Condition Assessment of Railway Tunnel Deformation Based on the Use of an FBG-Based Monitoring System

3.1.6 Fiber Optic Current Sensor for Electrified High Speed Railway Traction Power Supply System

3.1.7 Description and Assessment of Radio Frequency Identification (RFID) Sensors for Rail Track Deformation Monitoring

3.1.8 Assessment of Self-Sensing Cement-Based Materials with CNT/NCB Composite Fillers for High-Speed Railway Monitoring

3.1.1 Train Axles Crack Detection Enabled by the Utilization of Guided Waves

Motivation

The major aim of this study is to provide a quantitative understanding on the elastic wave propagation in hollow cylindrical waveguides with a significant thickness-to-wavelength ratio. The work consists of two major parts:

1. Investigation of the cylindrical guided wave theory and understanding of various types of propagating waves and their characteristics; and
2. Utilization of the acquired knowledge to develop an effective damage detection methodology for railway axle inspection.

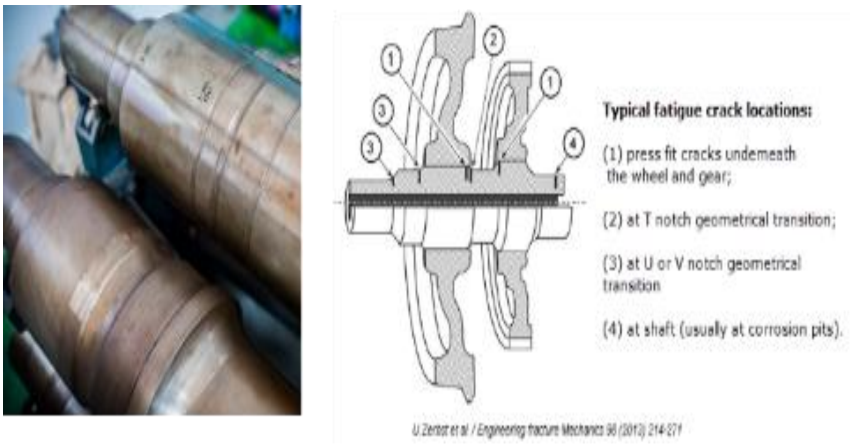


Figure 3.1 Typical fatigue crack in train axles

Wave Propagating Characteristics in Hollow Cylinders

Theoretical, numerical and experimental investigations are presented to facilitate understanding of wave propagations in thick-walled cylinders, to further enable potential damage detection applications. Various guided wave phenomena are discussed, including seemingly interlacing dispersion curves of axisymmetric longitudinal modes and the pseudo-symmetric relations of particle displacement patterns. Despite the anticipated complexity of wave propagation in thick-walled structures, the results of the preliminary investigations have been found promising in terms of potential inspection methods. Based on the in-depth understanding of the physical phenomena, a novel damage detection method employing near-field wave enhancement effects was established and examined.

Figure 3.2 Wave field & wave propagating characteristics: (a) Experimental set-up; and (b) FE model analysis result

<u>Detection of Cracks on Train Axles</u>

A thick-walled hollow axle structure is investigated. Three levels of damage identification were addressed, namely detection, localization and assessment of the crack. To optimize the effectiveness of the inspection, it was proposed that the excitation and sensing locations needed to be chosen at outer diameter transitions; thus allowing for the utilization of the enhancement-based approach when monitoring particular sections of the axle. The developed inspection methodology through Steps 1 (angular cross-correlation) to 4 (damage assessment) is summarized in the following figure. Additionally, a possibility of the introduction of a damage index (DI), i.e. a single-value signal change estimate, evaluated from 164 different signal analysis, for automation of the SHM analysis is indicated. Importantly, although in the current solution, all three levels of inspection are considered, depending on the specific monitoring system requirements, level 1 of the inspection may be considered as sufficient for the axle structural evaluation. Various numerical and experimental investigations were carried out to validate both the damage detection and the damage localization techniques. The results of the conducted analysis confirmed the feasibility of the wave enhancement effect for the surface inspection of the beneath wheel seats.

The baseline approach based on the evaluation of cross-correlation coefficients, has demonstrated a highly effective tool for angular localization of a crack. It should be noted that the cross-correlation analysis depends on the sensor location; thus, changes in the enhancement effect are intrinsically incorporated into that value. For determination of a crack location in the axial direction of the structure, the time-of-flight analysis using pulse-echo transducer configuration is an attractive approach. This, however, requires careful interpretation of the reflected signal, based on the geometry of the structure and the dominant wave components.

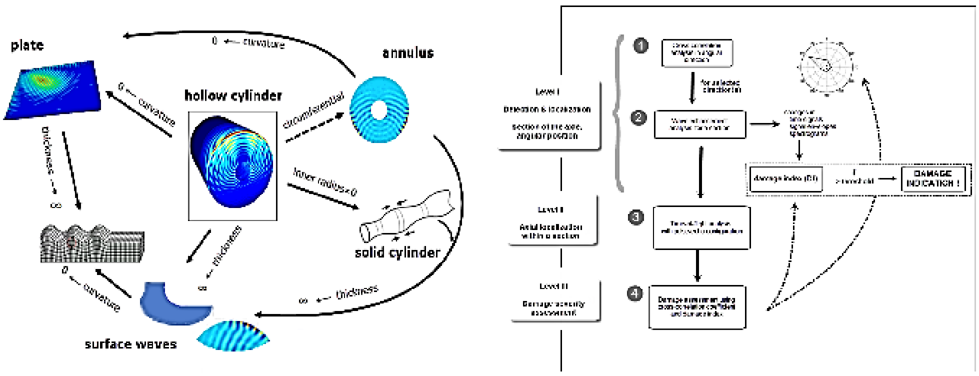


Figure 3.3 Scheme for crack identification

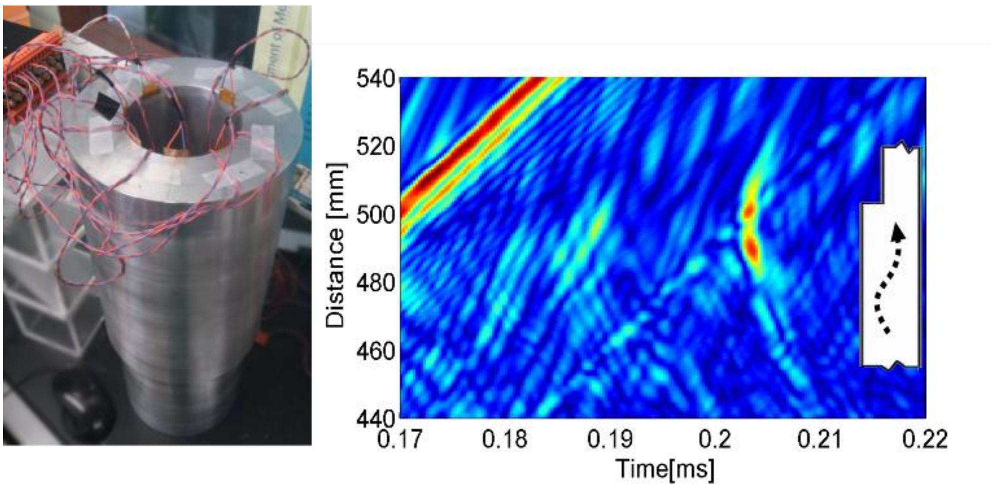


Figure 3.4 (a) Experimental set-up for damage detection and evaluation; and (b) Damage detection with the wave enhancement phenomenon

3.1.2 The Effects of the Application of Ultrasonic Guided Waves in the Structural Health Monitoring of High-Speed Railways

Motivation

High-speed railways are prone to develop various types of damage, such as cracks and corrosion. In the US, 64%~70% of accidents are due to derailments. The percentage of reported derailments has increased steadily over recent years. Most derailment accidents were caused by rail defects. To ensure railway system operation is safe and catastrophic accidents prevented, as well as, conventional offline rail track inspections, Non-Destructive Evaluation (NDE) demand based on-line monitoring techniques for rails, has been fast developing. As a mature NDE method, Ultrasonic Guided Wave (UGW) has been identified as a promising inspection tool for the structural health monitoring (SHM) of rail structures.

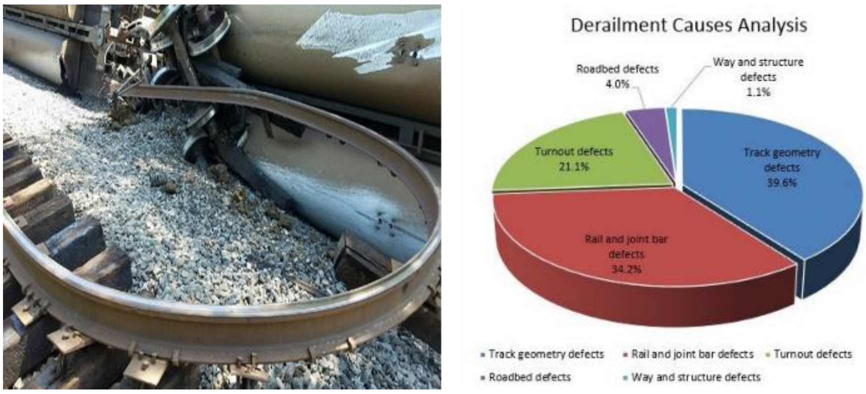


Figure 3.5 (a) Rail derailment accident; and (b) Derailment causes analysis

Introduction to Technologies

Guided waves can propagate over long distances without much energy loss, hence enabling large-scale structural inspections. Piezoelectric transducers have been widely investigated to generate and receive ultrasonic guided waves. They can be permanently installed on the host structures and achieve real-time structural sensing. Taking advantage of fiber Bragg grating (FBG) sensors and their immunity to electromagnetic interference quite common in rail systems, and long monitoring ranges, an FBG-PZT hybrid system has been developed using lead zirconate titanate

(PZT) as UGW actuators with FBG as receivers. It is of importance, however, to obtain an in-depth understanding of the guided wave phenomena within such complex waveguides. The Semi-Analytical Finite Element (SAFE) method has been developed, hence, enabling the provision of the dispersion relations and mode shapes of guided waves in complex waveguides. The Finite Element Method (FEM), however, is widely used for simulating elasto-dynamic wave propagation. Specifically, the Local Interaction Simulation Approach (LISA) using explicit finite difference formulations is proposed for the study of nonlinear interactions between guided waves and fatigue cracks.

Figure 3.6 Experiment overview: (a) Workshop; (b) Specimen; and (c) Data acquisition system

<u>**Experimental Investigation**</u>

In the experimental study, guided waves generated by piezoelectric sensors propagate along the rail track and interact with a 10-mm deep notches, machined by a thin emery cutter. These waves are partially transmitted and partially reflected at the damage site. The transmitter and receiver No. 1 work in a pulse-echo mode, to detect reflections from the damage, while the transmitter and receiver No. 2 work in a pitch-catch mode, to capture the transmitted waves. Agilent 33220A function generator and Tektronix TDS2024C oscilloscope are used to generate the interrogating waves and record the active sensing signals.

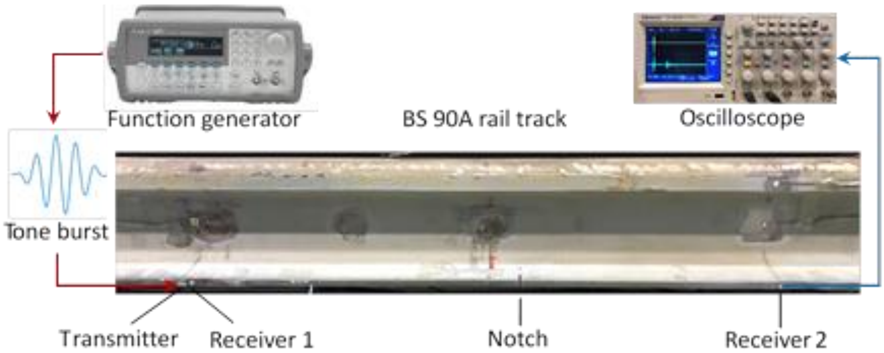


Figure 3.7 Experimental system setup

An LISA FEM approach is used in the study of ultrasonic guided wave propagation along the rail structure, to find the optimum position for sensor placement, and further to simulate the different behaviour evident between the guided waves and cracks.

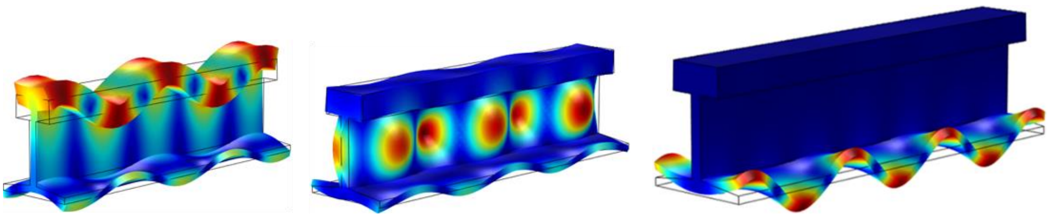


Figure 3.8 Model analysis results

<u>Data Processing and Analysis</u>

The lab test results have revealed that both pitch-catch and pulse-echo configurations provide good indications of damage existence, and experimental results match well with FEM simulations. Defects are well able to be detected in practical applications, with greater confidence when the results from the two approaches are synthesized, using multiple PZT transducers mounted on the switch rail.

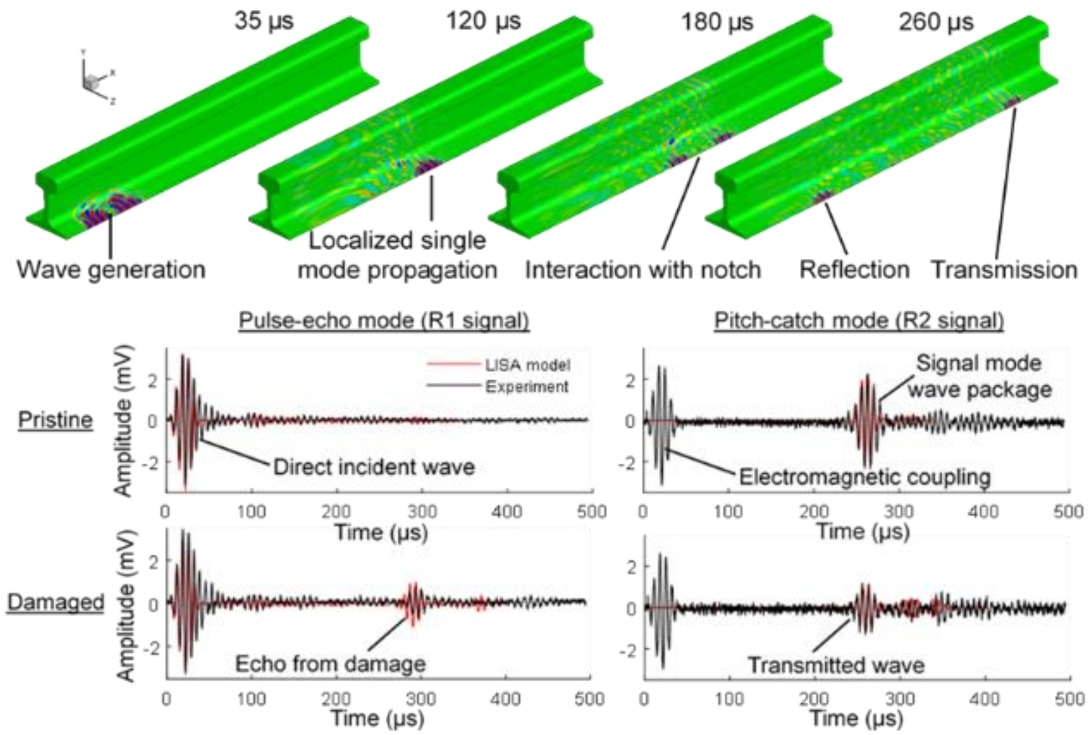


Figure 3.9 Comparison between experimental and numerical results

3.1.3 Incipient Damage Detection by the Employment of Nonlinear Guided Waves Excited by Magetostrictive Transducers

Motivation

The damage presence in railway systems, manifested in whatever form in such as train axles, rails, and so forth, can significantly jeopardize system operations and therefore safety without timely warning. Therefore, it is crucial to detect the appearance of initial damage in real time, and thus, have an opportunity to better enhance safety and extend the residual lifetime of structures in service, as well as effectively driving down exorbitant maintenance costs. A cousto-ultrasonic guided waves for damage identification is well known as an effective tool in structural health monitoring (SHM) due to characteristics such as a larger monitoring range and high sensitivity to damage. Based on the extracted features from the captured responses used for damage diagnosis, the guided wave based SHM method can be categorized into linear and nonlinear methods. The linear methods use damage scattering features causing their detection resolution to be limited by the wavelength of those guided waves in use. In contrast, the nonlinear methods usually rely on microstructural deficiencies in materials. Therefore, the nonlinear methods enable early detection of structural incipient damage, and significantly facilitate maintenance decisions. In this study, nonlinear guide wave based SHM methods are used to detect damage in the structures. The developed techniques can be potentially used for railway applications.

Figure 3.10 (a) Train rails; and (b) Train axles

Magnetostrictive Transducers for Guided Wave Excitation

In this study, magnetostrictive transducers (MSTs) are used to generate guided waves in plates. Basically, an MST contains these components:

1. A permanent magnet to create a static magnetic field;
2. Coils to generate a dynamic magnetic field;
3. A magetostrictive patch to pass deformation to the host structure under inspection. When the static field is parallel with the dynamic field, the magnetostrictive patch is elongated by means of the Joule effect. Through coupling between the patch and the host plate, Lamb waves can be generated. Similarly, if the static field is perpendicular to the dynamic field, shear deformation according to the Wiedemann effect is generated in the patch, thus inducing SH waves in the plate.

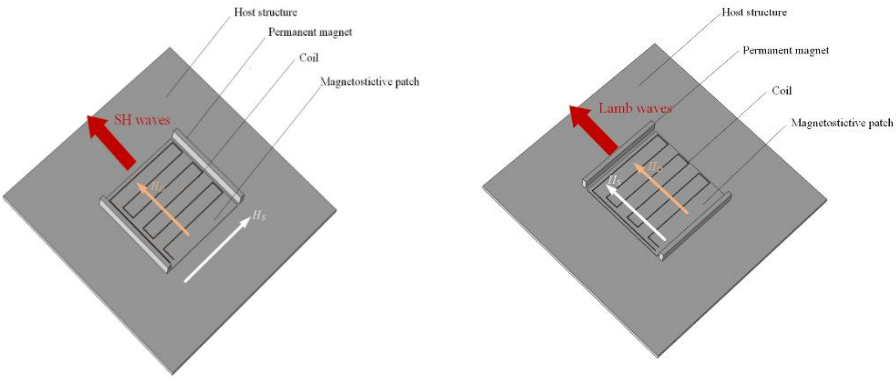


Figure 3.11 (a) Mechanism of Lamb wave generation by MST; and (b) Mechanism of SH wave generation by MST

Thermal Aged Damage Monitoring with Nonlinear Guide Waves

After mounting the MSTs on an aluminum plate, an ultrasonic test was conducted. Lamb waves were generated at 200 kHz with a pair of inverse excitations. A superposition method was adopted to separate the second harmonic responses. After having both linear and second harmonic time-domain signals, the complex wavelet transform was conducted to further extract their amplitude. Thermal age damage was then created in the laboratory. According to the current literature, microstructures tend to greatly change and incipient damage may occur during the thermal aging treatment. The plate was first heated to 350° in a certain zone and kept, for as such, as 2 hours. An ultrasonic test was then pre-conducted to record the linear and second harmonic wave amplitude after the plate cooled to room temperature. This process was repeated 5 times, giving the linear and nonlinear wave amplitude regarding different aging times.

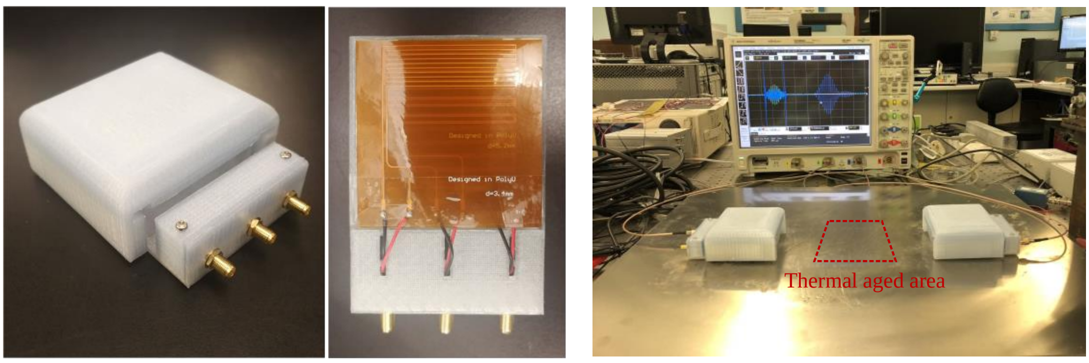


Figure 3.12 (a) Designed MST device; and (b) Set-up of the ultrasonic test

After the thermal aging treatment, no visible changes in the plate could be observed. Additionally, almost no changes were observed in the linear amplitude in the ultrasonic tests, thus indicating traditional methods fail to detect the changes in the thermal aging treatment. The second harmonic amplitude, however, experiences a dramatic increase after the thermal aging treatment, which means the thermal aged damage can be effectively detected by nonlinear guided wave based SHM methods. Thus, it is proven that the nonlinear guided wave based SHM methods are more sensitive to microstructural changes than the linear methods and therefore, in further applications, have the potential for the early detection of incipient damage in structures such as train axles and rails.

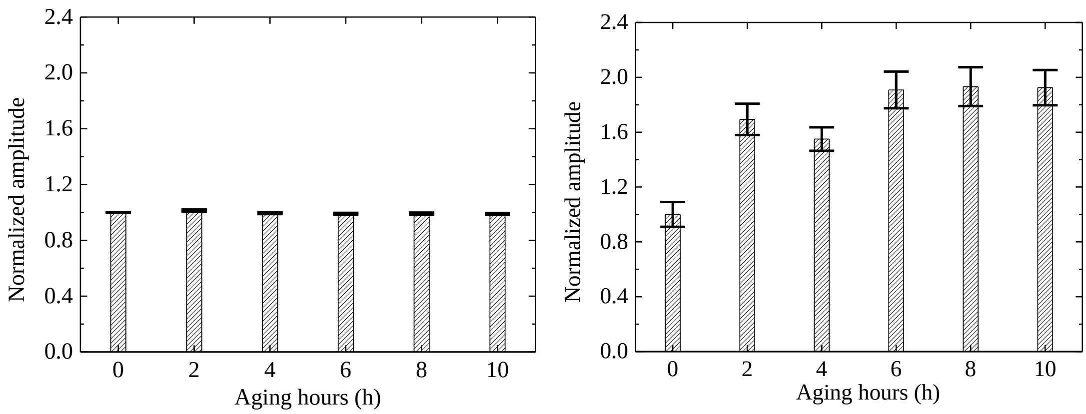


Figure 3.13 (a) Variation of linear wave amplitude with aging time; and (b) Variation of second harmonic wave amplitude with aging time

3.1.4 HSR Track Slab Condition Monitoring and Load Transmission Evaluation Enabled by the Use of Embedded FBG Sensors

Motivation

CNERC-Rail has launched collaborative research with the China Academy of Railway Sciences (CARS) on a project entitled "A full-scale study of load transmission on high-speed rail ballastless track structures". Accordingly, CNERC-Rail has developed a monitoring system based on embedded FBG sensors. This system, which fully considers the properties of the CRTSIII track slab, makes use of FBG sensing techniques to measure the dynamic strain of both track slab, and basement during train passage. Based on the monitoring data collected by embedded sensors, the load transmission from wheel/rail interaction to different layers of track structures can be analyzed.

Monitoring System

The CRTSIII slab track is a novel type of ballast less HSR track, widely adopted in newly built HSR lines in mainland China (as shown below). The devised system, which fully considers the structure properties of CRTSIII slab track, consists of multiple embedded FBG sensing arrays, a high-speed interrogator and a computer. The FBG arrays, which can quantify interior strains of concrete slabs at multiple location, are embedded in the slabs at construction and during the pouring system.

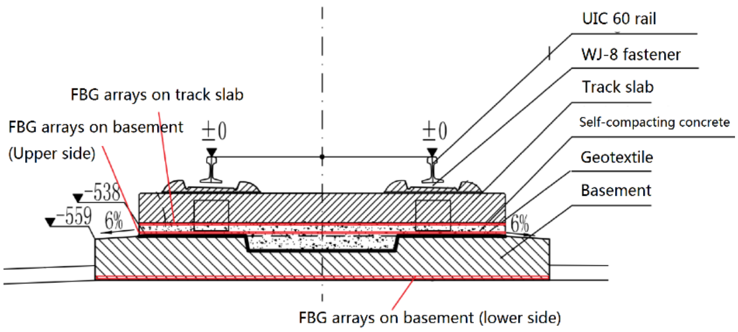


Figure 3.14 CRTSIII slab track and location of embedded FBG arrays

The sensing system consists of 12 smart Glass Fiber Reinforced Polymer (GFRP)-FBG with 7 measurement points and 36 embedded GFRP-FBG strain gauges (as shown below). These embedded sensors are set inside both the track slab and concrete basement of Beijing-Shenyang HSR at up to 120 locations, including 60 on the track slab and 30 on the basement slab, in subgrade-tunnel transition sections, and another 30 on the basement in subgrade sections.

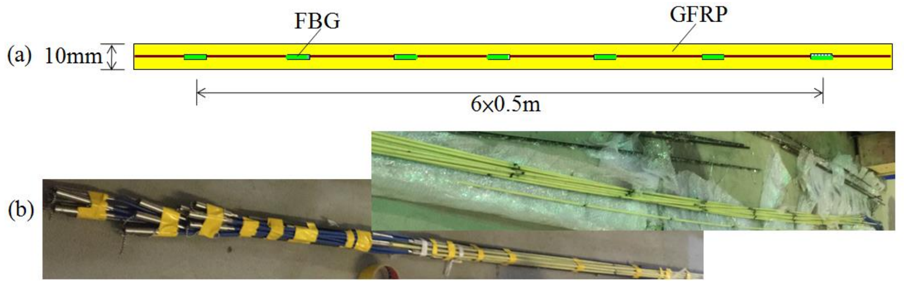


Figure 3.15 Embedded GFRP-FBG array: (a) Schematic; and (b) Photo of sensor

Figure 3.16 Embedded GFRP-FBG strain gauge: (a) Schematic; and (b) Photo of sensor

Online Monitoring

The implementation and testing of embedded sensors were conducted in May 2017 and February 2018 (as shown below). The Beijing-Shenyang HSR began a trial operation in Match 2018, and the strain responses of the track slab and basement to the wheel load excitations were collected by the embedded sensors. The time histories of the strain responses to train load excitation are shown in the figure below.

Figure 3.17 Implementation of embedded GFRP-FBG sensors on Beijing-Shenyang HSR

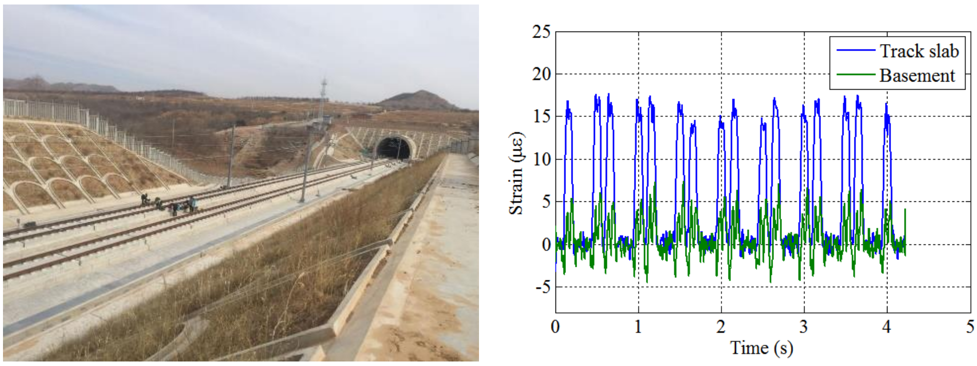


Figure 3.18 (a) On-site test of embedded GFRP-FBG sensors; and (b) Time histories of strain responses of track slab and basement

3.1.5 Real-Time Condition Assessment of Railway Tunnel Deformation Based on the Use of an FBG-Based Monitoring System

Introduction to Technology

Design of FBG Bending Gauge with Temperature Self-Compensation

An FBG bending gauge comprising two turnable arms, a hinge, a hinged support and two FBGs with one rotational degree of freedom is designed for measuring the rotation angle variation between the two arms.

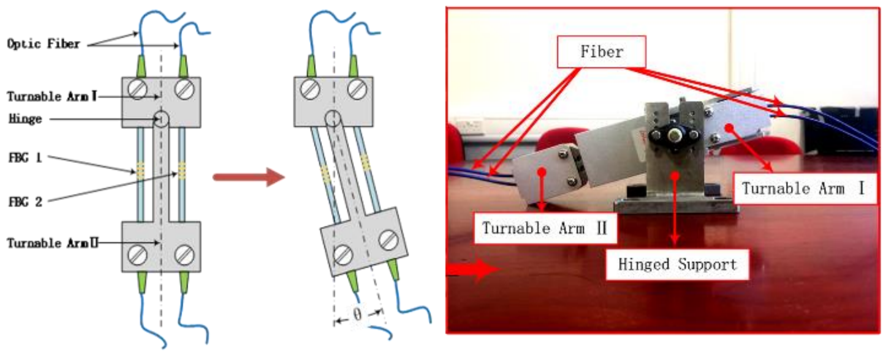


Figure 3.19 FBG bending gauge

The measurement error induced by the environment temperature variation can be compensated automatically by the proposed scheme. An experiment was carried out to verify the temperature compensation capacity of the devised FBG bending gauge.

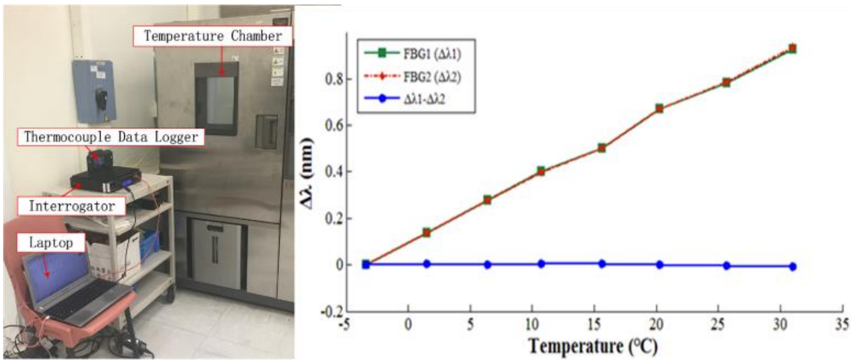


Figure 3.20 Experiment for verifying temperature compensation capacity of FBG bending gauge

Railway Tunnel Deformation Monitoring Using FBG Bending Gauges

The array of FBG bending gauges are attached to the tunnel and, then further connected with rigid rods to form a chain reflect the tunnel deformation.

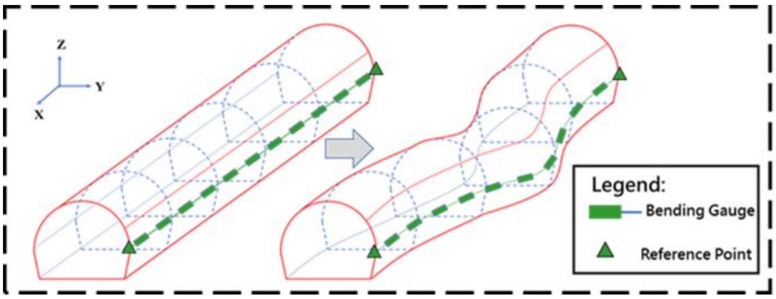


Figure 3.21 Railway tunnel deformation monitoring using FBG bending gauges

The deformation profile in one direction is obtained through the calculation of a relative rotation angle between any two adjacent bending gauges in a chain.

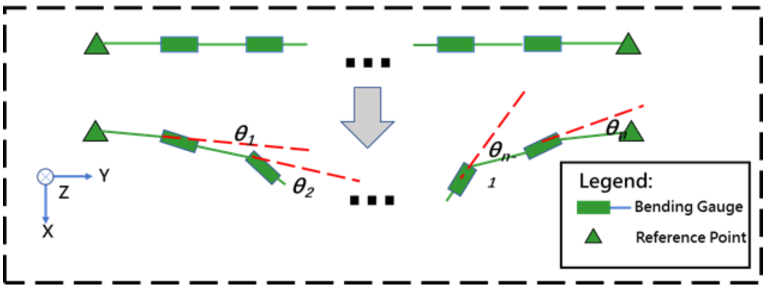


Figure 3.22 Principle of deformation quantification

The tunnel deformation and rail irregularity can be estimated in a spatial-temporal view, by deploying FBG bending gauges on tunnel walls and rail slabs.

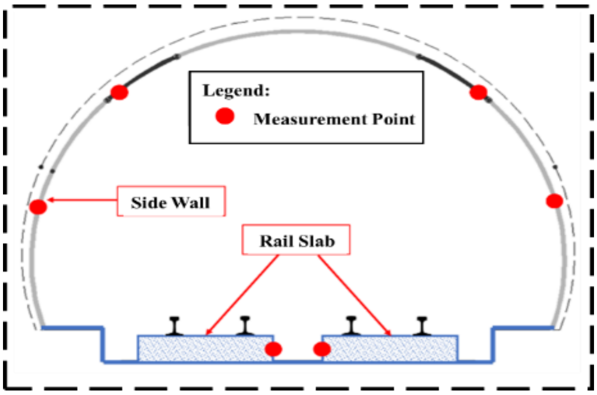


Figure 3.23 Future development of tunnel deformation monitoring system by deploying bending gauges on tunnel walls and rail slabs

Scheme of Proposed Railway Tunnel Deformation Monitoring System

As illustrated, the system consists of four subsystems:

- Sensing system based on FBG bending gauges
- Data acquisition system
- Data storage, processing and analysis system
- Real-time display and visualization system

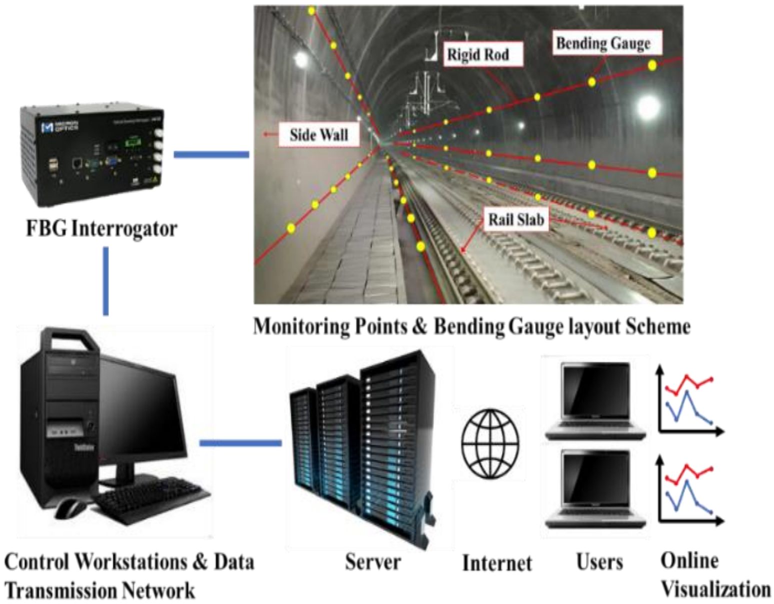


Figure 3.24 Configuration of devised system

Experimental Investigation

In the experimental study, the platform is built to simulate different patterns of railway tunnel deformation. It includes:

- Tunnel deformation simulation system generating transverse movements.
  - Test platform
  - Electronic liner module
  - Zigbee wireless node
  - Control panel

- LVDT based test control system precisely testing the generated movements.
  - Five LVDTs
  - A LVDT Data logger
  - A controller

- FBG bending gauge - based railway tunnel deformation test system
  - Five FBG bending gauges connected by rigid rods (3000 mm)

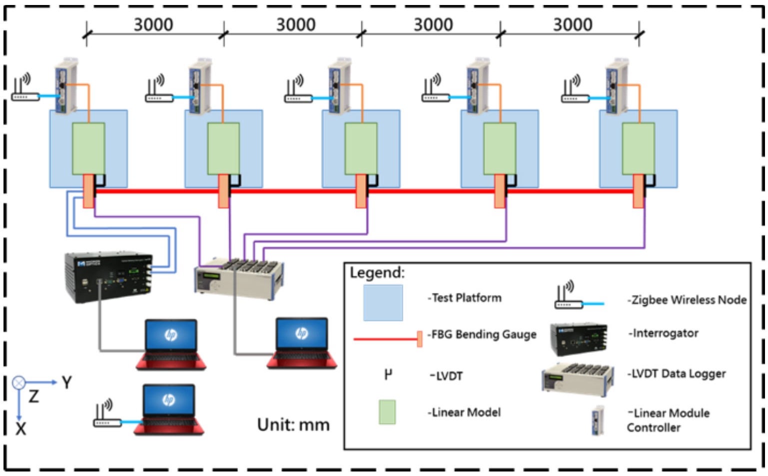


Figure 3.25 Schematic of devised system and LVDT-based system

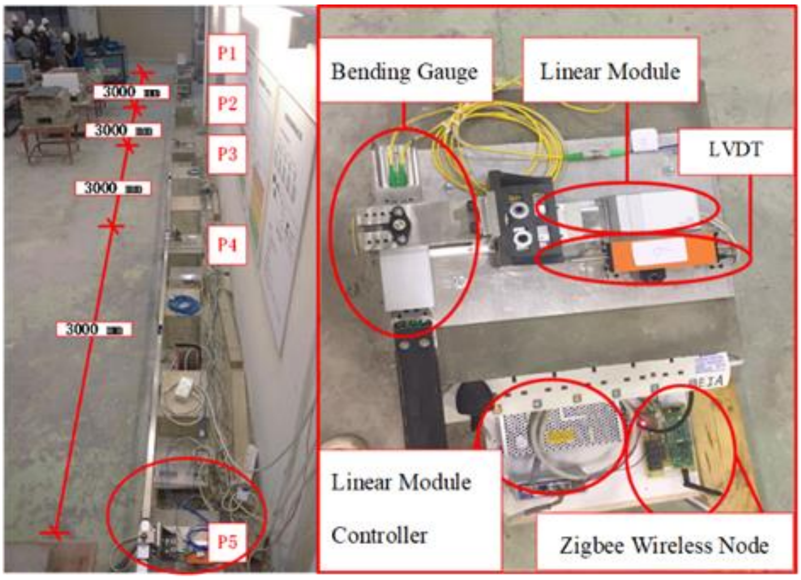


Figure 3.26 Experiment setup

3.1.6 Fiber Optic Current Sensor for Electrified High-Speed Railway Traction Power Supply System

Figure 3.27 Fiber optic current sensor (FOCS) for electrified railway traction power supply system

Table 3.1 Specifications for FOCS

	Description	Specifications
1	Voltage level	10KV-1200KV
2	Range of rate current (AC/DC)	1000A-1MA (Max. 3MA)
3	Primary/Secondary using Environment	-40 to +70°C /-10 to 55°C
4	Measure/protection accuracy (25 harmonic waves)	IEC 0.2S grade, 0.2 grade, 5P30/40
5	Data sampling frequency	4 to 12.5KHz
6	Data signal output standard	IEC 60044-8, 61850-9/2
7	Power Supply	According to the site conditions
8	Installation Method	flexible or Fix
9	Application	HRS Intelligent Power Network /Intelligent State Grid

3.1.7 Description and Assessment of Radio Frequency Identification (RFID) Sensors for Rail Track Deformation Monitoring

Advantages: Battery-free, Remote Wireless Collect Data

Figure 3.28 Deformation of railway due to change of the internal stress or temperature

Figure 3.29 RFID strain & temperature sensors installed for collecting railway data by remote wireless RFID readers

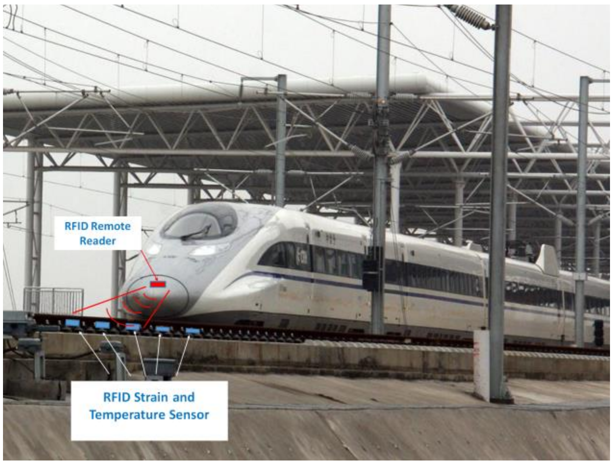


Figure 3.30 Data collection by a wireless RFID reader installed on moving high-speed trains

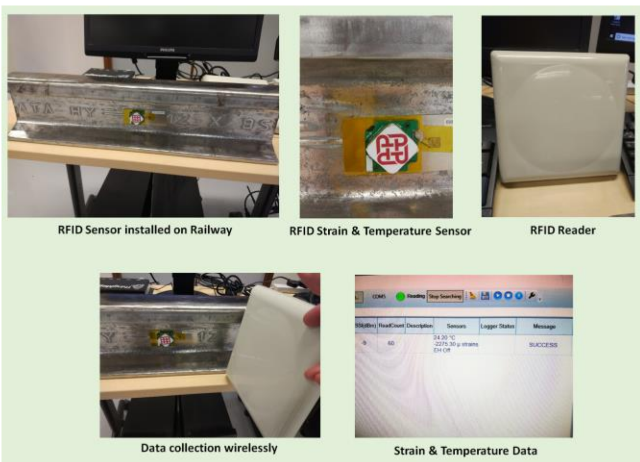


Figure 3.31 Laboratory experiment of the RFID strain & temperature sensing system

<u>**RFID Sensor Design for Railway Concrete Slab Uplift Measurement**</u>

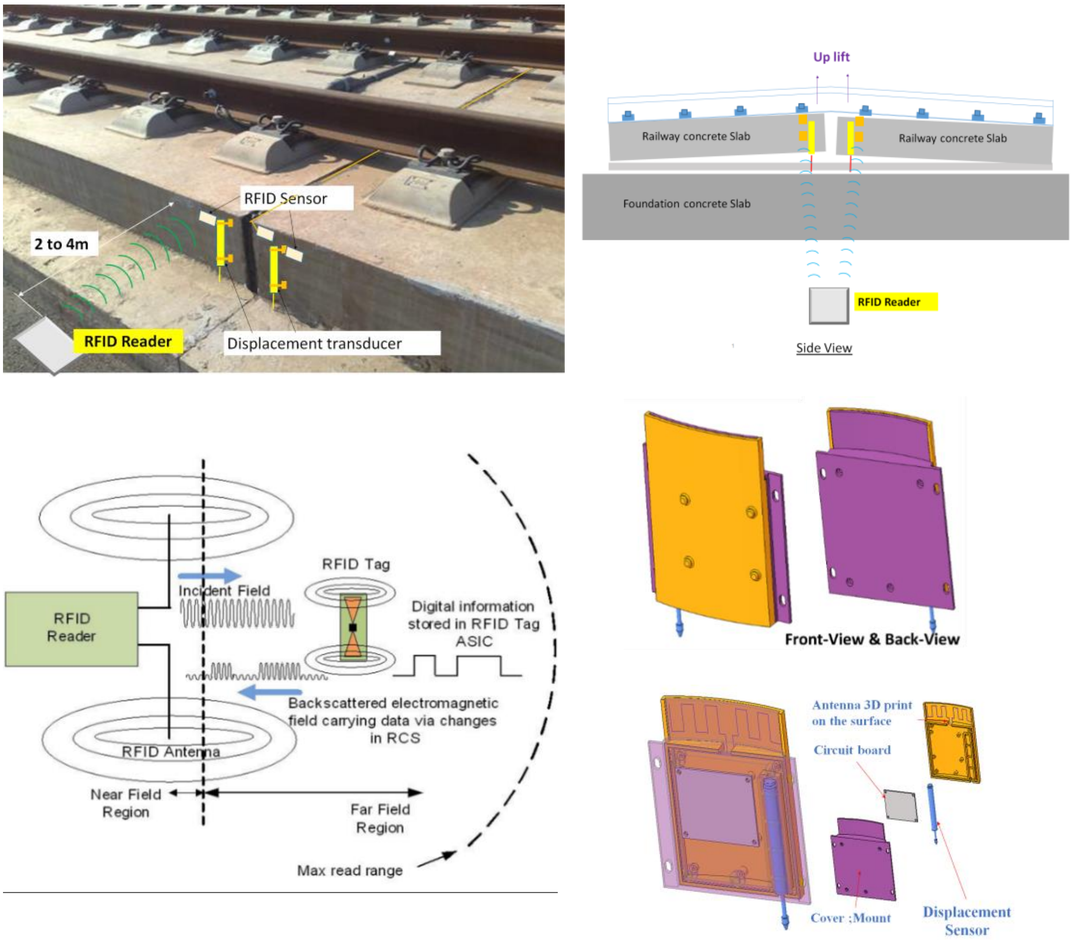


Figure 3.32 3D Printing housing design prototype

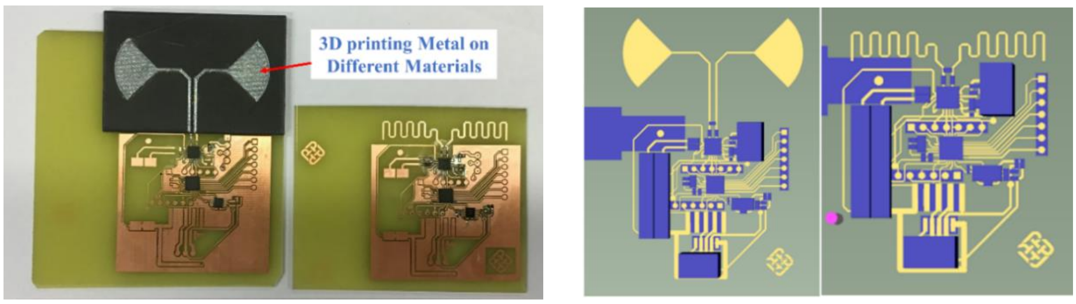


Figure 3.33 PCB design & prototype

3.1.8 Assessment of Self-Sensing Cement-Based Materials with CNT/NCB Composite Fillers for High-Speed Railways Monitoring

Motivation

With the rapid development of high-speed rail, monitoring systems that allow real-time and continuous monitoring of the structural and operational conditions of trains, are becoming increasingly important. Conventional monitoring systems in railway infrastructure use strain gauge sensors to detect dynamic train load, train speed, axle load, and wheel flats based on a variation of responses caused during the train passage. Conventional sensing techniques, however, have drawbacks such as poor durability, low sensitivity, low survival rate, and unfavorable compatibility with concrete structures. A new type of sensor with self-sensing cement-based materials (SSCMs) has recently emerged with the development of conductive cementitious composites. SSCMs are structural materials which can be incorporated as part of the railway system structure. They also have the ability to recognize strain, stress, cracking, and damage from the influence of change in the volume of electrical resistivity during the loading process. Unlike other sensors, the cementitious nature of the SSCMs enables such sensors to be directly embedded prior to casting. When embedded, the SSCM forms a mechanically strong bond with the monitored structure and creates a continuously distributed set of strain sensors within the structure. The SSCMs also have a service-life, similar to the matrix structure, thus enabling long-term applications with limited maintenance. Therefore, SSCMs have the requisite potential to be used as a suitable and long-term addition to railway infrastructure. This study, for the first time, investigates the feasibility of the SSCMs with self-assembled carbon nanotube/nano carbon black (CNT/NCB) for HSR monitoring.

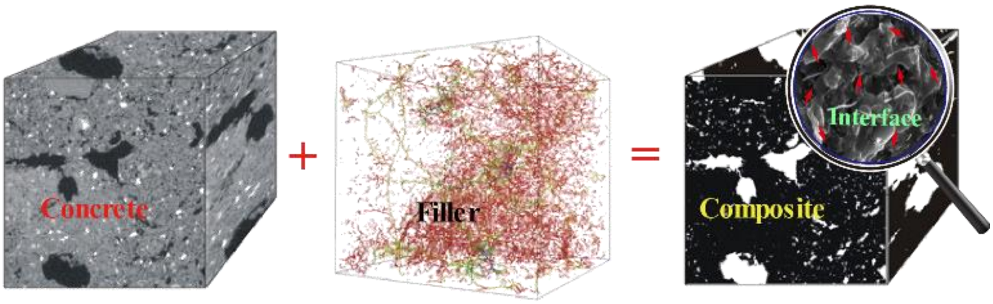


Figure 3.34 Self-sensing cement-based materials with CNT/NCB composite fillers

__Properties of the CNT/NCB__

- Excellent electrical conductivity
- Cooperative improvement effect of both CNTs and NCBs
- Improved dispersion of CNTs and NCBs in cement matrix

Properties	Description/Value
Mass ratio of CNTs/NCBs to hybrid/wt.%	40/60
Shape	Grape clusters
Specific gravity/g·cm^{-3}	2.0
Specific surface area/m^2·g^{-1}	65-75
Electrical resistivity/Ω·cm	10-3
Outer diameter of CNTs/nm	>50
Length of CNTs/μm	10-20
Specific surface area of CNTs/m^2·g^{-1}	>40
Tap density of CNTs/g·cm^{-3}	0.18
Particle size of NCBs/nm	23
Specific surface area of NCBs/m^2·g^{-1}	125

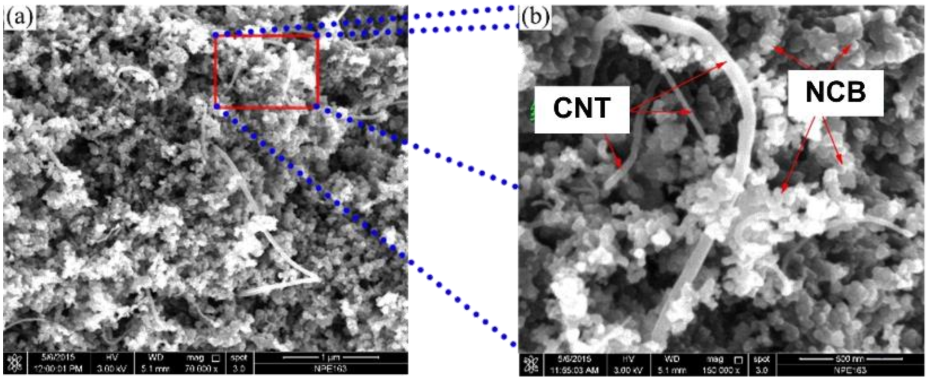


Figure 3.35 SEM images of CNT/NCB composite fillers

Sensor Fabrication

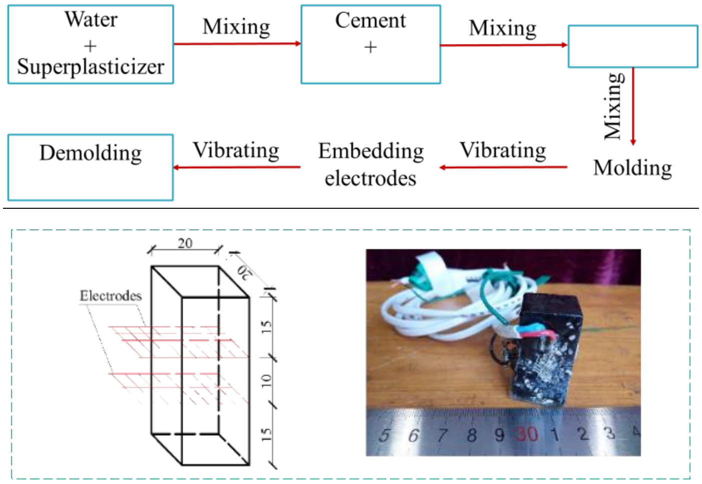


Figure 3.36 Fabrication and dimension of SSCM sensor

Sensor Performance

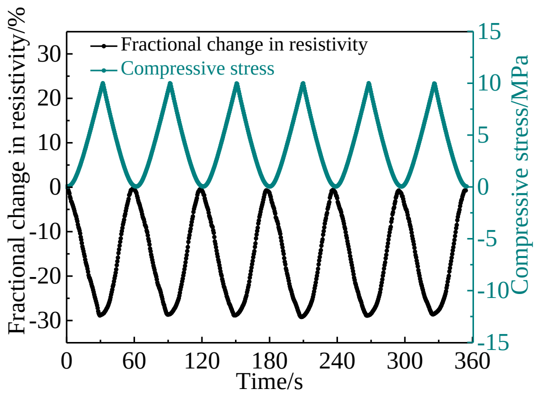


Figure 3.37 Behavior under repeated compression (10 MPa)

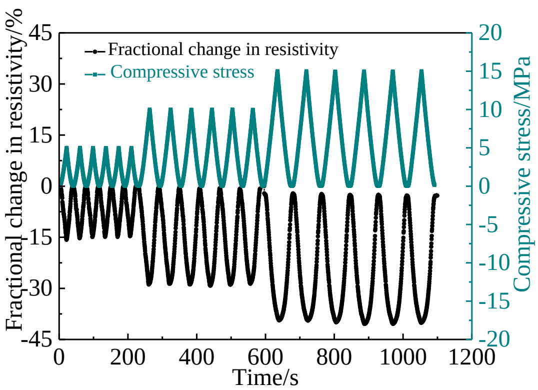


Figure 3.38 Behavior under different compressive stress amplitudes

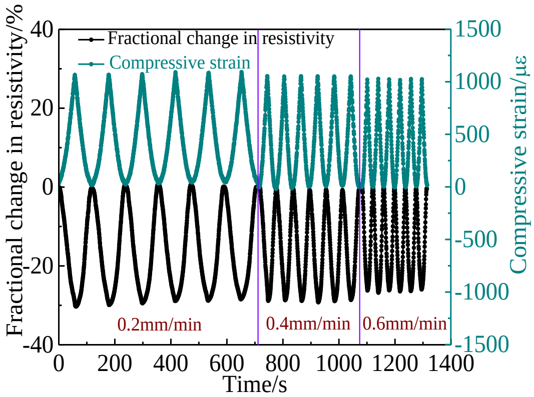


Figure 3.39 Under different compression rates

- Compressive strength： 32.58 MPa
- Elasticity modulus ： 9.23 GPa
- Stress sensitivity： 2.89 %/MPa
- Gauge factor: 282.32
- Nearly 140 times the gauge factor of a conventional resistive strain gauge

Application

- Trail test on Shanghai-Hangzhou high-speed railway (K1293)

Figure 3.40 Test site

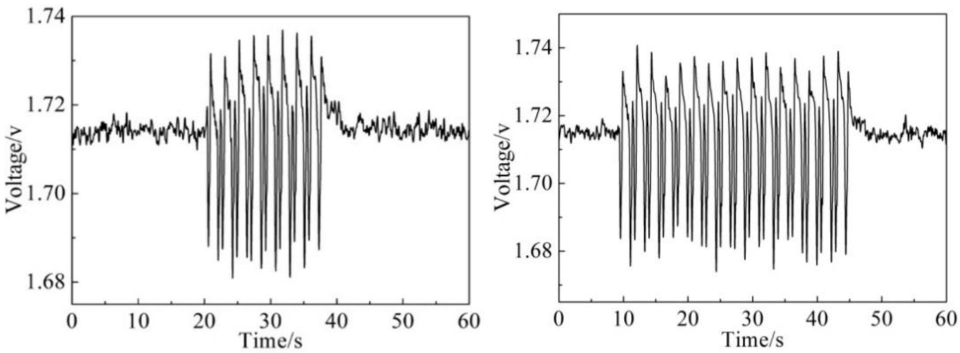


Figure 3.41 Data collected from 8-car train and 16 car train respectively

Conclusions

The SSCMs with CNT/NCB composite fillers embedded directly into a concrete slab track have the ability to be used for: (i) axle counting; (ii) speed detection; and (iii) weight measurement.

3.2 Safety and Reliability Assessment by Data Mining

3.2.1 Sparse Bayesian Learning for Structural Health Monitoring in High-Speed Railways

3.2.2 Optimum Life-Cycle Inspection of Rail Structures Undergoing Corrosion and Fatigue

3.2.3 Bayesian Probabilistic Approach regarding Acoustic Emission-Based Rail Condition Assessment

3.2.4 Probabilistic Fatigue Life Assessment of High-Speed Trains Using In-Service Monitoring Data

3.2.5 High-Speed Railway Thermal Strain Extraction Using Bayesian Blind Source Separation

3.2.6 An On-Board Condition Monitoring System for High-Speed Train Bogie

3.2.7 Automated Damage Detection for High-Speed Train Wheels Based on a Bayesian Dynamic Linear Model

3.2.8 High-Speed Rail Damage Detection of Wheels based on Convolutional Neural Networks

3.2.9 GNSS-Based Ionosphere Observation of Fast-Moving Trains (GIOFT)

3.2.10 High-Speed Rail Condition Monitoring by Compressive Sensing-Based Data Acquisition

3.2.1 Sparse Bayesian Learning for Structural Health Monitoring in High-Speed Railways

Motivation

Modern transportation heavily relies on high-speed railway, hence the safety of such trains is one of the most important concerns of railway operators all over the world. Although much attention and effort has been paid to maintaining safe operations, unfortunately, from time to time, accidents still occur, leading to economic loss, human injury and time loss for both passengers and rail engineers. Rail inspection and maintenance work is constantly conducted, but it still appears to be insufficient from preventing accidents from occurring. Structural health monitoring (SHM) has been widely used in recent decades for on-line condition monitoring of the rail infrastructure and vehicles to enhance operational safety. As the railway system is open and complicated and with great uncertainties, the option of data-driven statistical models is thought to be a suitable method to determine current states of railway structures. Sparse Bayesian learning (SBL), as a novel data-driven approach, has a good generalization ability with fewer kernel functions. Hence it is particularly applicable for online and real-time railway structure monitoring. More importantly, SBL establishes the statistical model in a probabilistic framework, with various uncertainties taken into consideration.

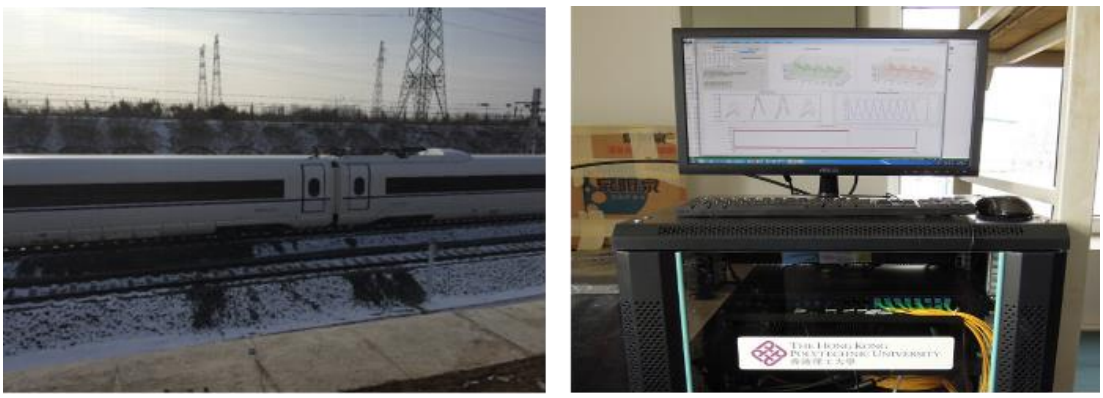


Figure 3.42 Online condition monitoring for high-speed trains

Applications

In this project, two case studies are used to illustrate the benefits of the SBL regarding the structural health monitoring of high-speed rail.

Case study 1: S-N curve fitting

A number of vehicle components are subjected to thermal and mechanical loading cycles. Thus, the fatigue life assessment of these components is of great importance for the global safety, efficiency and hence secure availability of high-speed rail. The design fatigue curve (S-N curve) is usually based on strain-controlled fatigue tests of small polished specimens. With the use of SBL, a probabilistic S-N curve can be derived hence enabling various uncertainties appearing in the fatigue life assessment. Included are such as environmental effects the variability of experimental options and results and also those related to mechanical models and applied loading.

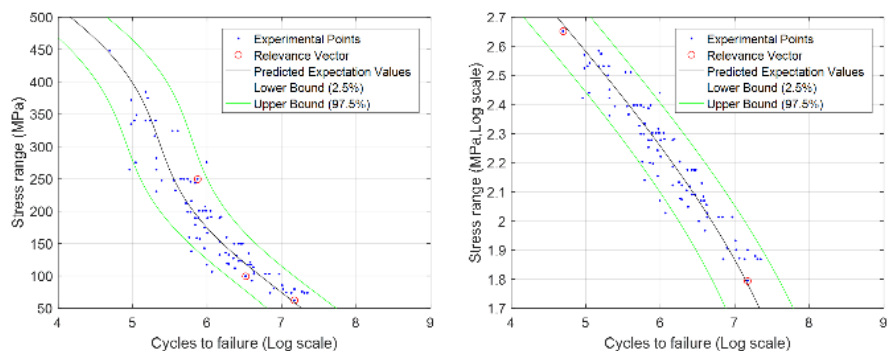


Figure 3.43 Probabilistic S-N curve derived by SBL

Case study 2: Wheel condition diagnosis

Wheel condition diagnosis is of vital importance to ensure HSR safety and reduce maintenance cost. Early detection of wheel defects and the subsequent timely maintenance benefit passenger safety and the economics of HSR maintenance. Although wayside monitoring systems have been extensively used for wheel condition monitoring, efficient real-time diagnosis and prognosis related to wheel conditions still need further investigation. With the use of SBL and the availability of historical monitoring data, a data-driven statistical model can be easily developed. The latter would make a timely contribution to the healthy maintenance of healthy wheels. On-line monitoring data can thus be used for wheel condition assessment in real-time and wheel defects can be identified by Bayesian model selection.

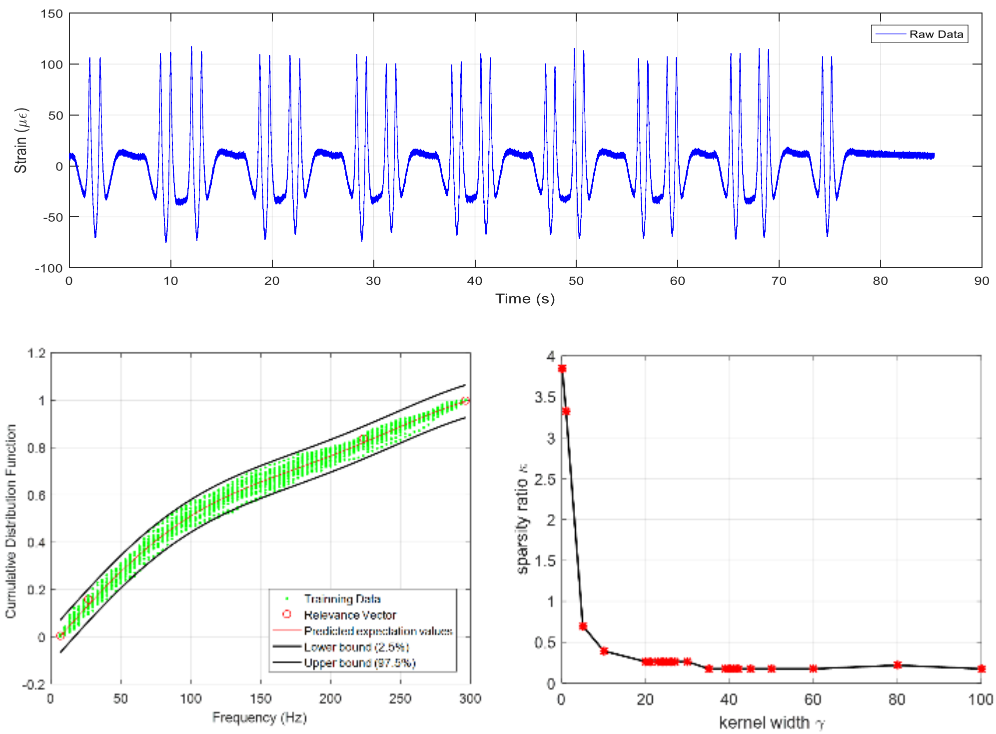


Figure 3.44 Online wheel condition monitoring and defect identification based on SBL

<u>Conclusions</u>

- SBL can reach a competitive level of generalization accuracy, by dramatically utilizing fewer kernel functions, a considerable saving in memory and computation in a practical implementation, being the implication;
- Another advantage of SBL is its standard formulation as a Bayesian probabilistic model. Bayesian probabilistic models can predict and convey measures of uncertainty.

3.2.2 Optimum Life-Cycle Inspection of Rail Structures Undergoing Corrosion and Fatigue

Motivation

Aging railway structures may suffer from deterioration associated with corrosion and/or fatigue, resulting in a reduction of their resistance to damage. The reduction can lead to structural failure. Additionally, load effects on structures contain high levels of uncertainty and may exceed the associated design loads. Both inspection and maintenance of aging railway infrastructures are necessary to ensure satisfactory structural performance during their life-cycle. Corrosion and fatigue could have significant effects on the structural performance and reduce the performance levels. Therefore, it is essential to be constantly aware and thus prepared for adverse consequences associated with failure under corrosion and fatigue. Additionally, there are significant and further uncertainties associated with corrosion and fatigue models. This project aims to provide a probabilistic methodology for optimum inspection and maintenance planning of rail structures in an attempt to be both prepared for risk under corrosion and fatigue and hence have the ready solutions to prevent any potential accidents.

Figure 3.45 Aging railway structures/components with corrosion and fatigue problems

Lifetime Optimum Inspection

The life-cycle maintenance of railway infrastructures is of vital importance in the prevention of corrosion and fatigue failure and subsequently accidents on line. A decision tree model is used in this project to illustrate a potential inspection and maintenance process and as shown in Figure 2.5. The structural deterioration effects associated with corrosion and fatigue are incorporated in the process. Overall, the optimization developed in this study aims to determine optimum lifetime inspection schedules for rail structures. Two objectives are minimized simultaneously in this bi-objective optimization procedure: (a) the life-cycle maintenance costs considering inspection and repair costs, and (b) the annual value of risk.

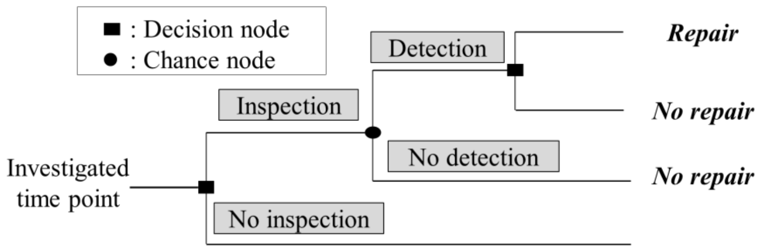


Figure 3.46 Inspection and maintenance process characterized by decision tree model

Within this optimization procedure, the design variables are inspection and repair timings. The maximum number of lifetime nondestructive inspections, in addition to time and reliability constraints is specified. Genetic Algorithm (GA) is adopted in this study to solve the bi-objective problem. The optimization module sends the candidates for the design variables to risk and cost modules. The performance module delivers the value of one objective, which is the annual risk value experienced during the investigated time horizon, to the optimization module. The cost module returns the total expected maintenance costs to the optimization module. Finally, after an adequate number of iterations, the optimization module provides the Pareto optimum front for the lifetime inspection planning. This approach can be utilized to provide multiple decision-making choices.

Case Study

The effects of corrosion and fatigue on the rail structures are assessed. The components comprising the investigated structures are exposed to different aggressive environments, consequently, the component corrosion rate varies. The entire system is divided into five different sections: S1, S2, S3, S4, and S5. Different sections are subjected to different structural deterioration scenarios, hence the relevant risk is different. Thus, it is of vital importance to determine the most critical section during the service life of the rail structure.

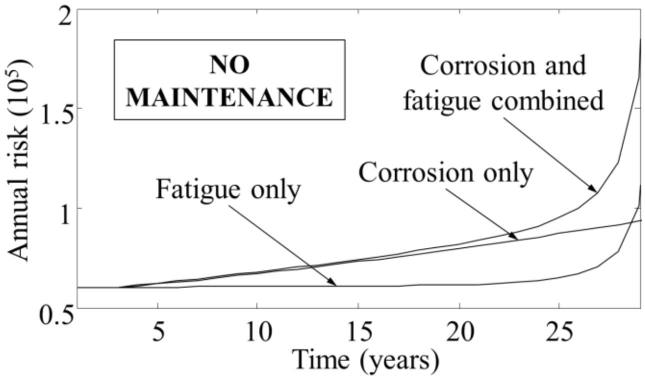


Figure 3.47 The effects of corrosion and fatigue on annual risk of structure

The risk increases gradually with time. Consequently, it is vital to reduce the risk under corrosion and/or fatigue to ensure the structural performance above the prescribed performance level during the investigated time interval.

The optimal maintenance strategy for the investigated rail structure is obtained by using optimization techniques. In this project, the bi-objective optimization problem is solved using the Non-dominated Sorting GA II (NSGA-II).

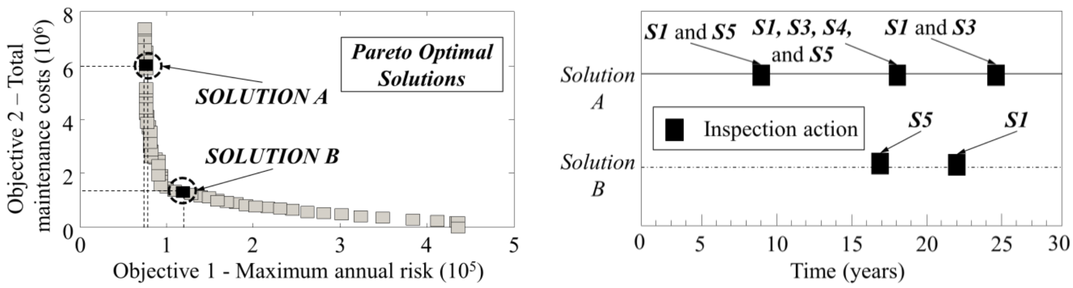


Figure 3.48 Bi-optimization problem and solution for rail infrastructure inspection

Overall, this project proposes a holistic and quantitative approach for the life-cycle inspection and maintenance optimization of rail structures considering the effects of corrosion and fatigue. The proposed methodology can be used to assist decision making regarding maintenance activities.

3.2.3 Bayesian Probabilistic Approach regarding Acoustic Emission-Based Rail Condition Assessment

Motivation

Undetected defects have the potential to lead to breakdown of a rail signaling system, service interruption and catastrophic consequences such as derailment. Significant tensile stress at low temperatures and non-uniform distribution of the stress across different sections due to loosening or partial rupture of fasteners may arise. Most of Nondestructive Evaluations (NDE) can only be maneuvered offline for periodic inspection at regular intervals. Thus, Acoustic Emission (AE)-based SHM method, which exploits the abrupt energy release triggered once a train passes across a cracked rail section, would be an appropriate supplement to and even a substitute for NDE. The AE method is based on the phenomena that transient waves are generated through the rapid release of strain energy during the crack expanding process. In this study, lead zirconate titanate (PZT) sensors are used to capture the transient wave.

Figure 3.49 (a) PZT sensor deployed on rail; and (b) Rail crack

Data-Driven Model Development for Damage Identification

For data collected by implemented sensors on operating railway lines, featured responses caused by rail crack expansion are normally obscured by intense vibrations, due to wheel/rail interactions, together with other environmental interferences. A probabilistic framework has been developed enabling the quantitative assessment of similar crack damage in rails under varying environmental and operational conditions. In this event, three core elements are evident: (i) a frequency-domain nonparametric structural health index (SHI) with its real and imaginary parts constituting a health condition pattern; (ii) data-driven reference models governed by the SHI, elicited by the use of Bayesian regression and also historical data captured from intact rails for baseline prediction; and (iii) the Bayes factor and its probabilistic confidence to quantify the discrimination between new observations representative of the current rail condition and model predictions.

The SHI *h* is defined as:

$$h = Q\bar{T}$$

Two reference models, $I_h(R_h)$, which expresses the imaginary part of SHI as a function of its real part and $R_h(I_h)$, which expresses the real part of SHI as a function of the imaginary part, are formulated to achieve a comprehensive assessment. $R_h(I_h)$ can be expressed as:

$$R_h(I_h) = f(I_h) + \varepsilon(I_h)$$

where $\varepsilon(I_h)$ is additive random noise, and $f(I_h)$ is expressed as a linear combination of nonlinear basis functions, which are herein taken as Gaussian distribution functions

$$f(I_h) = \sum_{k=1}^{L} \omega_k \phi\left(I_h, I_{h\_k}\right) = \phi^T \omega$$

The case for $I_h(R_h)$ is similar. With the Bayes factors B_R for $R_h(I_h)$ and B_I for $I_h(R_h)$, the synthetic Bayes factor B_f determined by the above two approaches is, respectively,

$$B_f = \max(B_R, B_I)$$

$$B_f = (\omega_R B_R + \omega_I B_I)/\omega$$

where $\omega = \omega_R + \omega_I$, $\omega_R = ||\boldsymbol{R}_{his} - \boldsymbol{f}_{his}||^{-1}$, and $\omega_I = ||\boldsymbol{I}_{his} - \boldsymbol{f}_{his}||^{-1}$. Here $||\boldsymbol{R}_{his} - \boldsymbol{f}_{his}||$ and $||\boldsymbol{I}_{his} - \boldsymbol{f}_{his}||$ are the Euclidean norm of modeling errors resulting from the training process.

Case Study

A PZT-based online monitoring system has been designed for AE-based rail defect detection. A total of four PZT sensors were fixed symmetrically on the two rails in the vicinity of the railroad turnout. Two closely spaced sensors to guarantee certain redundancy are attached on each rail. The signals from the PZT sensors are continuously acquired by a data acquisition unit on the site and before transmittance to a control room nearby. A database has been established with gradually acquired data upon the passage of trains each of a different type, subsequent weight, carriage number, and speed. The signals are intercepted such that the segment generated by the passage of one coach can be obtained before the filtering process. All indices fusing the filtered signal components are centered to have a zero mean and scaled to have unitary standard deviation before executing training and prediction, and conversion to their actual scales for further processing.

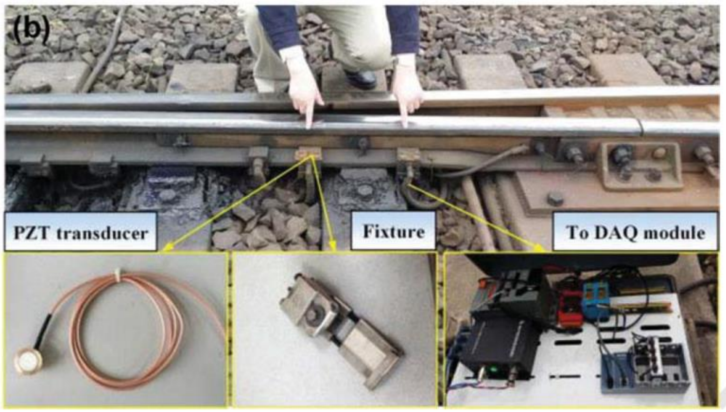


Figure 3.50 Online condition monitoring system for railroad turnout

Models are trained using data collected from field tests for health condition assessment, any model distinguished from the "healthy" model indicates existence of rail crack.

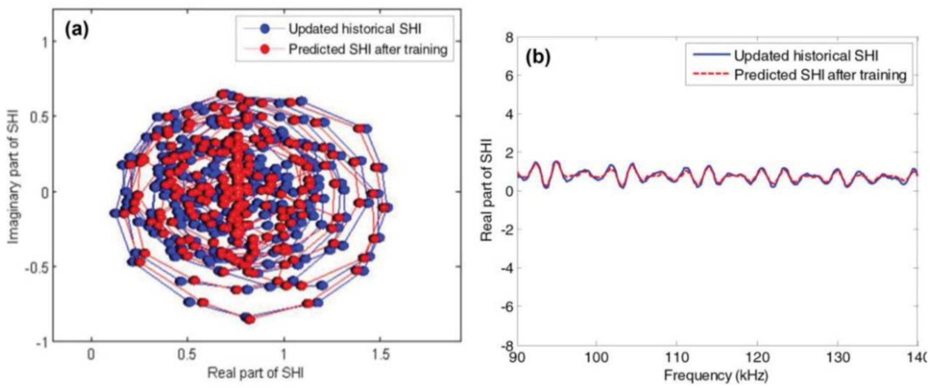


Figure 3.51 Updated index and model predictions: (a) Pattern comparison; and (b) Output comparison

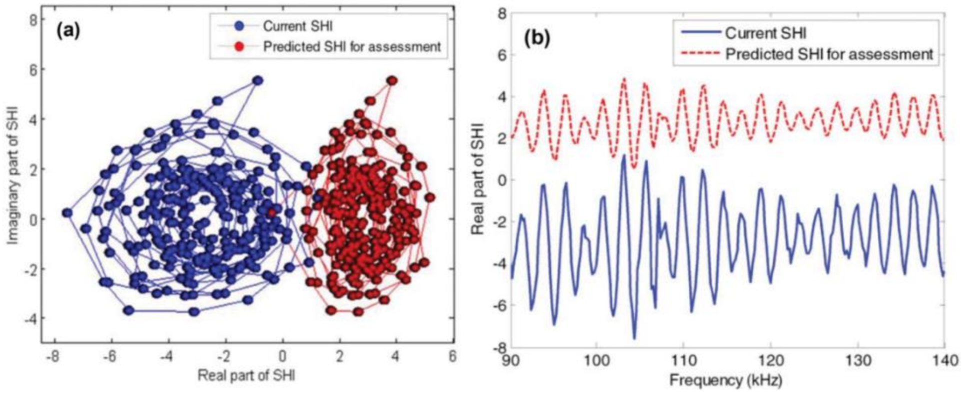


Figure 3.52 Current index and model predictions: (a) Pattern comparison; and (b) Output comparison

3.2.4 Probabilistic Fatigue Life Assessment of High-Speed Trains Using In-Service Monitoring Data

Motivation

A proper and feasible fatigue life assessment method helps reduce train operation and maintenance costs and improve train safety. Uncertainties in materials and in-service stresses, however, vary the estimated results of train fatigue life. In recognition of this, probability approaches are more reliable and feasible for fatigue life assessment. Two major aspects motivate such research:

- Current railway standards do not consider uncertainties in the stress histories (e.g. accident damages, degradation, long-term changes);

- Probabilistic approaches are beneficial to better decision making.

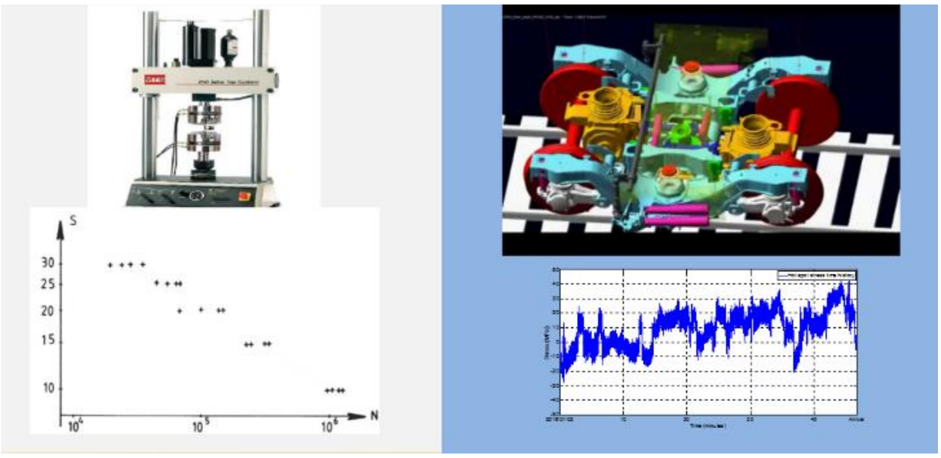


Figure 3.53 (a) Fatigue assessment for vehicle components based on experiment; and (b) Online condition monitoring

Methodology

A Bayesian fatigue life assessment method is developed using in-service monitoring data of high-speed train. The fatigue life prediction results are calculated using the estimated posterior distributions of material parameter values and the established posterior distribution of in-service stress spectra according to the MCMC algorithm.

$$F = \frac{0.5H}{\int_0^P \frac{f(s)}{N_s} ds} = \frac{0.5H}{\frac{n_{tot}}{C} \int_0^P f(s) s^m ds}$$

The application of the MCMC technique for probability distribution function (PDF) calculation:

$$P(F \mid s, S, N) = \iiint P(F \mid s^*, c, m) \times P(s^* \mid s) \times P(c, m \mid S, N) ds^*, c, m$$
$$\approx \frac{1}{M} \sum_{K=T-M+1}^{T} P(F \mid \mu, \sigma_t^2, c, m)$$

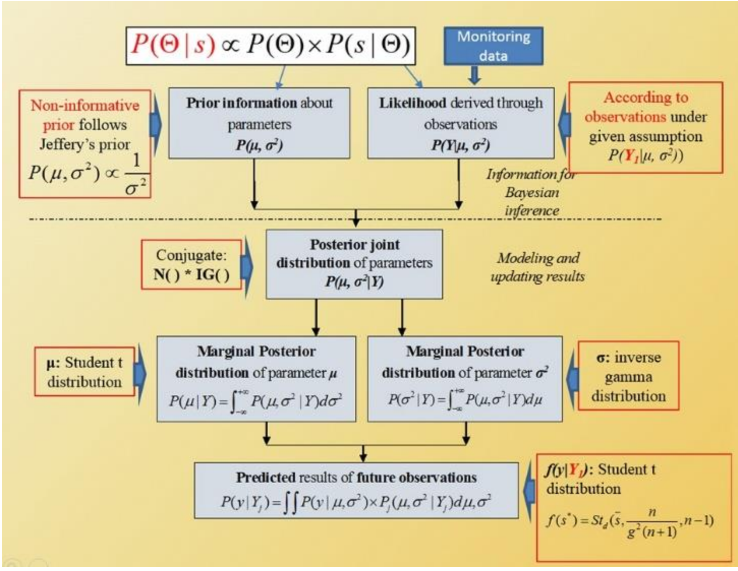


Figure 3.54 The procedure of Bayesian fatigue life assessment for high-speed train components

<u>Application</u>

The above method is verified with the monitoring data from a welded component of a train running on a high-speed railway in China. In addition, as stress concentration largely affects fatigue life of a welded joint, the hot spot stresses, obtained from the monitoring data are also integrated into the method. Assessment and prediction results show capability and good performance of the proposed method. This Bayesian method is especially suitable for the fatigue life assessment of a high-speed train, as when the monitoring period is sufficient, the collected information and continuous monitoring data can be used for further necessary updating.

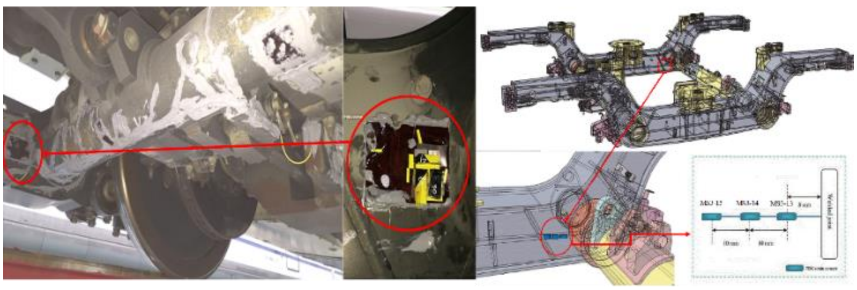


Figure 3.55 Verification of proposed method on in-service high-speed train

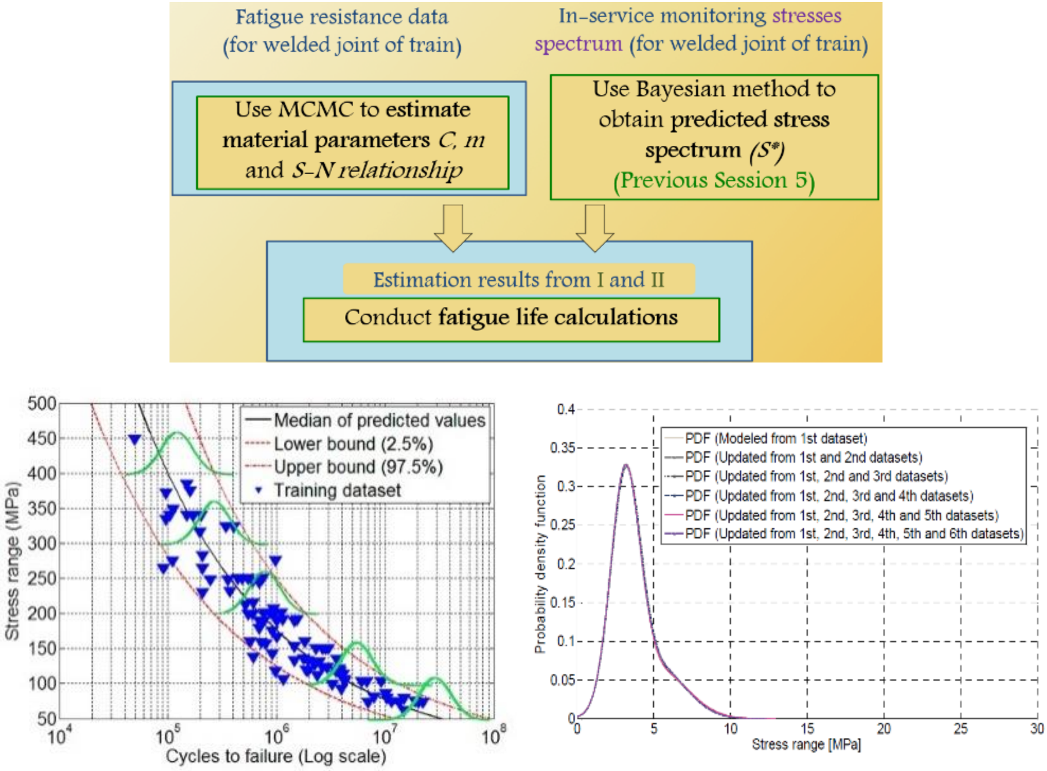


Figure 3.56 Stress spectrum prediction by Bayesian fatigue assessment

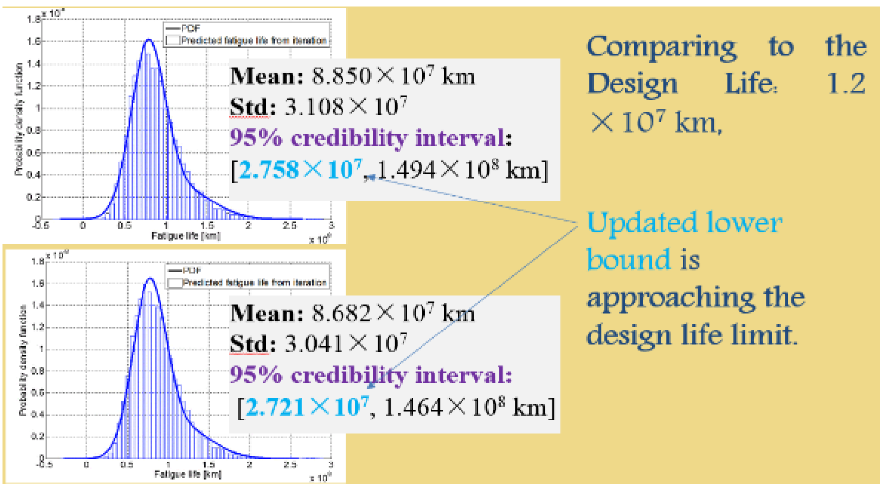


Figure 3.57 Fatigue prediction results

Results

- The uncertainties in material properties and in-service stress histories can be made use of by the proposed Bayesian fatigue life prediction model;
- Information from the estimated fatigue life by the Bayesian method can help improve maintenance work.

3.2.5 High-Speed Railway Thermal Strain Extraction Using Bayesian Blind Source Separation

Motivation

The collected high-speed railway strain data is extremely important for the health monitoring of each train, as it gives a direct and unique insight into structural real deformation caused by outside excitations. Environmental factors, however, such as temperature, will also introduce a significant variation to the data and severely influence the health assessment results. To eliminate the disturbance of thermal impact on the monitoring data, a hierarchical Bayesian model for blind source separation (BSS) problem is explored in this study. Due to its expressive power, the Gaussian process (GP) is exploited as the distribution source for the thermal strain signals. The real strain data of an operational high-speed train bogie is provided to evaluate the performance of the above method.

Methodology

The aim of the linear BSS is to instantaneously reconstruct the source signals and their mixing function from sole observations, but with system noise contamination possibly undetermined. Solving the BSS problem in the context of Bayesian inference, the measurement errors and uncertainties can be explicitly accounted for and quantified. To accommodate the temporal non-white thermal strain in the high-speed railway sensing system, the GP, which commonly works for regression problems, is exploited in this case, as the source prior to handling the BSS problem. The Markov Chain Monto Carlo (MCMC) method is applied in an attempt to sample the parameters from the whole posterior distribution support, thus preventing problems arising in some local optimal point estimation methods.

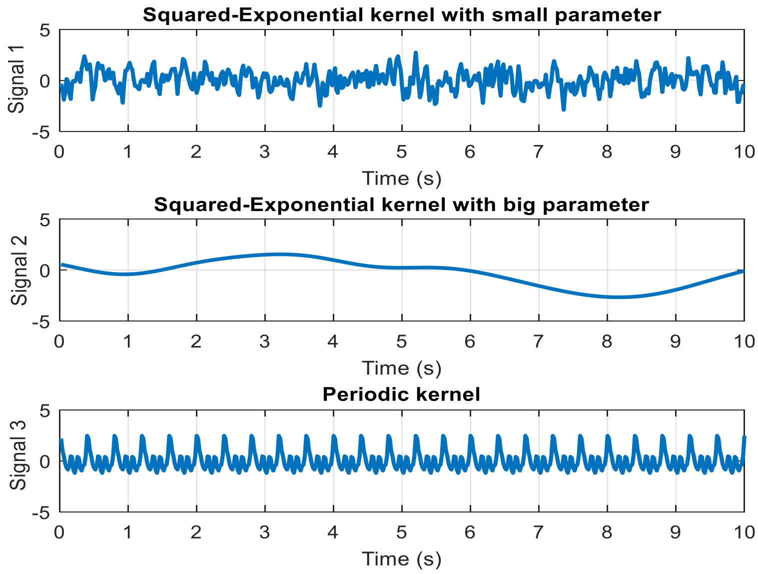


Figure 3.58 Signals generated from the GP

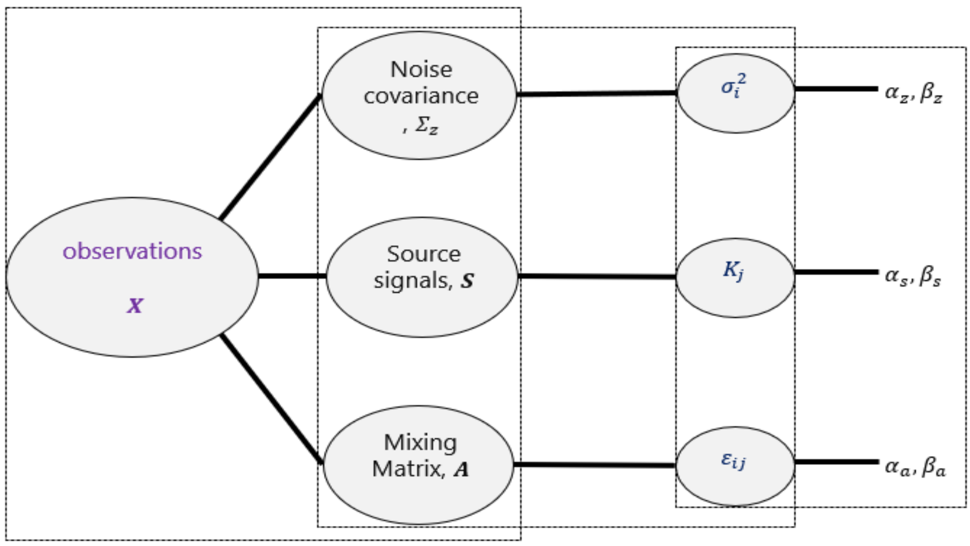


Figure 3.59 Graphic model for Bayesian BSS

Algorithm to sample using MCMC

For r = 0 to k, do

1. Sampling source $\boldsymbol{S}_j^{(r+1)}$ from $\mathcal{N}\left(\boldsymbol{S}_j|u_s, \Sigma_s\right)$;
2. Sampling mixing matrix $\boldsymbol{A}_{(:,\boldsymbol{j})}^{(r+1)}$ from $\mathcal{N}\left(\boldsymbol{A}_{(:,\boldsymbol{j})}|u_A, \Sigma_A\right)$;
3. Sampling noise covariance matrix $\Sigma_z^{(r+1)}$ from $\prod_{i=1}^{m} IG\left(\sigma_i^2|\alpha_n, \beta_n\right)$,;
4. Sampling the mixing matrix hyperparameter $\varepsilon_{ij}^{(r+1)}$ from $\prod_{i=1}^{m}\prod_{j=1}^{n} \mathrm{IG}\left(\varepsilon_{ij}^2|\alpha_x, \beta_x\right)$,;
5. The probability of accepting the proposed new h_j^* is $\min\left(1, \frac{p\left(\boldsymbol{S_p}|h_j^*\right)p\left(h_j^*\right)q\left(h_j|h_j^*\right)}{p\left(\boldsymbol{S_p}|h_j^{(r)}\right)p\left(h_j^{(r)}\right)q\left(h_j^*|h_j^{(r)}\right)}\right)$

Until convergence.

Figure 3.60 The sampling procedure based on MCMC

<u>Thermal Strain Extraction for High-Speed Train</u>

The strain data was collected by the onboard monitoring of an in-service train running on the Lanzhou-Urumqi high-speed railway.

Figure 3.61 Thermal strain extraction for online monitoring data

<u>Conclusions</u>

Two independent sources are reconstructed. It is found that the first source has a high correlation coefficient with the temperature data and therefore, can be viewed as the thermal strain.

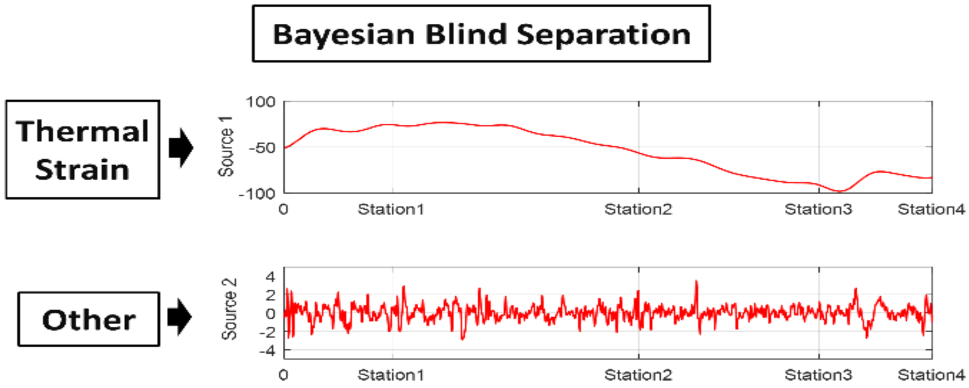


Figure 3.62 Results of thermal strain extraction based Bayesian BSS

3.2.6 An On-Board Condition Monitoring System for High-Speed Train Bogie

Motivation

- Fatigue analysis is conducted for critical bogie components using the collected strain data;
- Because wheel condition affects the overall stability of bogies, a comparison of the structural performances before and after the wheel lathing / re-profiling is made;
- The difference in the measured accelerations, when a train passes over ground, runs across bridge or through tunnel is also investigated.

To understand the structural performance of an in-service high-speed train, fiber Bragg grating (FBG) strain sensors, temperature sensors, accelerometers are deployed together with other types of sensors. These sensors are installed at critical locations within the high-speed train components.

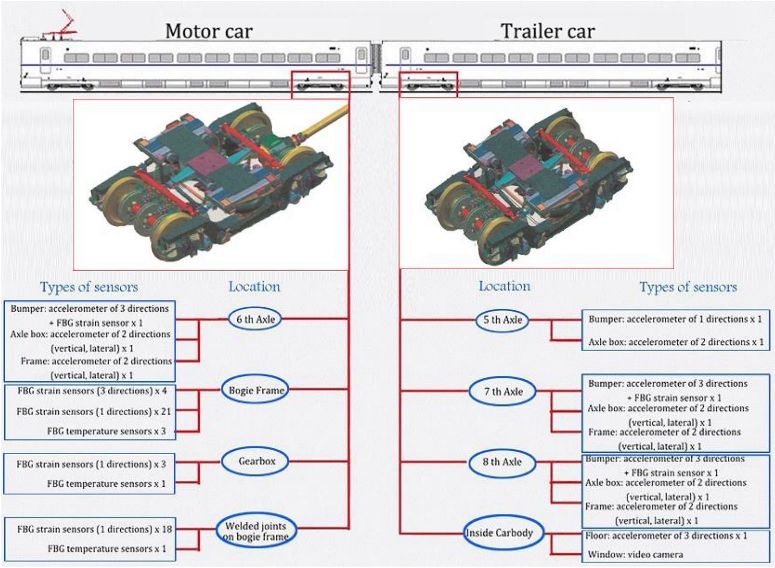


Figure 3.63 Configuration of on-board condition monitoring system for high-speed train bogie

On-board Monitoring of In-service Train

The on-board monitoring was conducted during train routine operations for one month. The total route length of the HSR line is over 1000 miles. The monitoring work includes two stages: before and after wheel lathing/re-profiling. During the first stage the train was monitored for 5 round-trips before wheel lathing, during the second stage the train data was collected for the other 11 round-trips, after wheel lathing. The monitoring data from these train trips was then used to enable analysis of the bogie conditions.

Discoveries from Data Analysis

Fatigue analysis: Statistical analysis of the monitoring data shows that, among data collected from all implemented points, data collected by the sensor near the welded joint of the connection of tubular crosspiece and bogie frame has the largest mean stress range values. The figures below show the monitored hot spot stress time histories for the aforementioned welded joint during two train trips. Fatigue life assessment was carried out for the welded joint. The assessment result is 137 years, longer than the demanded service life (30 years). This indicates the train component is safe in terms of fatigue resistance.

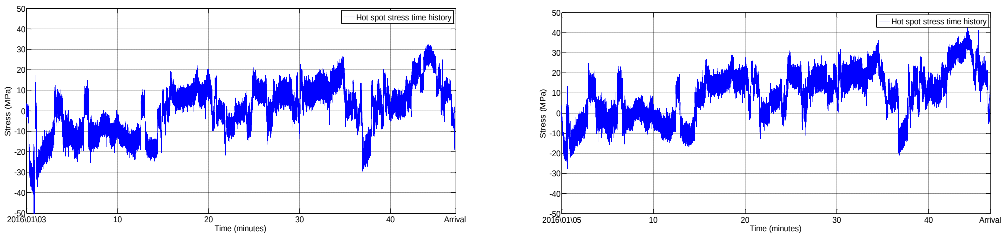


Figure 3.64 Online monitoring data of bogie strain

Structural performance affected by wheel lathing: After the wheel lathing in a depot, the recorded radius deviations of the train wheels were around 0.02 mm. The figures below show the responses before and after wheel lathing on the bogie component and the floor inside the car body. It shows that small wheel radius changes by wheel lathing significantly affect the structural performance of train.

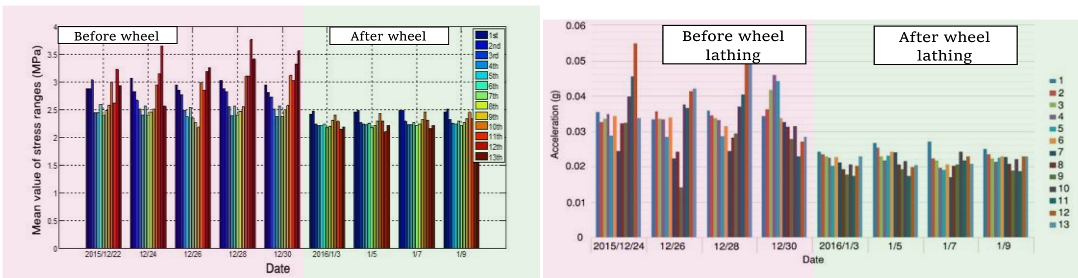


Figure 3.65 Vehicle dynamic responses before and after wheel lathing

Ride comfort levels when train passed through different sections: The ride comfort levels of the monitored train were evaluated and compared using the Sperling index under different conditions (crossing bridges, tunnels and ground/subgrade). The monitored acceleration data (vertical and lateral directions) was collected from the accelerometers inside the car body. The overall Sperling index value is below 1.0. Among all the operating conditions, the Sperling index value of trains crossing through tunnels is the highest (0.9123 and 0.9351), and the Sperling index value of train crossing bridges is the lowest (0.5970 and 0.7086).

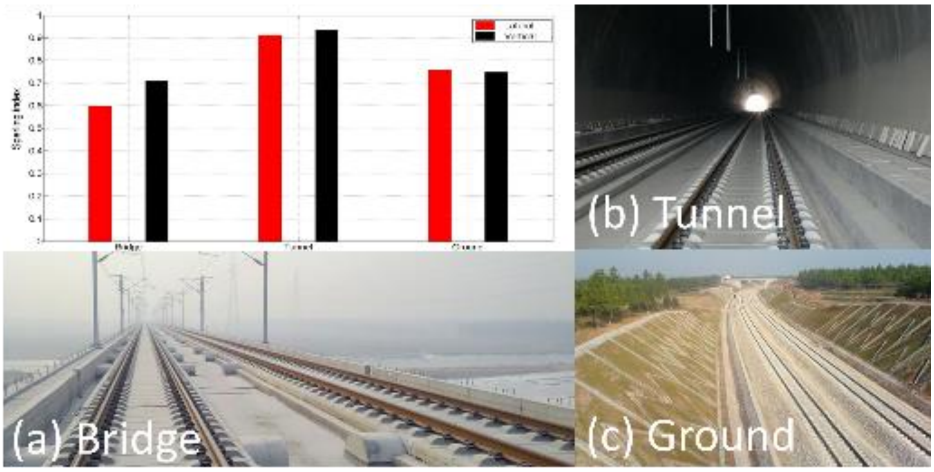


Figure 3.66 Comfort assessment results corresponding to different sections along the rail line

3.2.7 Automated Damage Detection for High-Speed Train Wheels Based on a Bayesian Dynamic Linear Model

Motivation

The condition of train wheels is one of the major concerns of the railway system. This is not only because of the dynamic behavior the rail vehicle is highly dependent on the shape of the wheel profiles but also, because wheel conditions are related to the train safety when in operation. Although common nondestructive testing (NDT) techniques play a significant role in detecting train wheels defects, most of them can only be conducted offline at periodic intervals, regardless of the working condition changes and progressive deterioration of train. On the contrary, onboard monitoring systems deployed on bogie frames can provide continuous and real-time strain measurement during in-service operation of a high-speed train and have the potential to detect defects and assess deterioration states of the wheels. This study aims at developing a real-time damage detection algorithm based on Bayesian dynamic linear model (BDLM) for high-speed train wheels by using the online monitoring data. It incorporates logics for (i) prognosis; (ii) potential outlier detection; (iii) beginning of change identification; and (iv) damage extent and uncertainty quantification.

Application

To verify the proposed damage detection method, a case study with the use of monitoring strain data from an in-service high-speed train bogie was conducted. An optical fiber sensing based monitoring system was designed for performance deterioration detection of high-speed train wheels. In this system, a total of 52 FBG strain sensors were affixed on the train bogies. Onboard monitoring was conducted on an in-service train running on Lanzhou-Urumqi High-Speed Railway and lasted for 18 days (9 round-trips). During the monitoring period, the train ran at its normal speed of around 160 to 200 km/h. Sampling rate for all sensors was set as 5000 Hz.

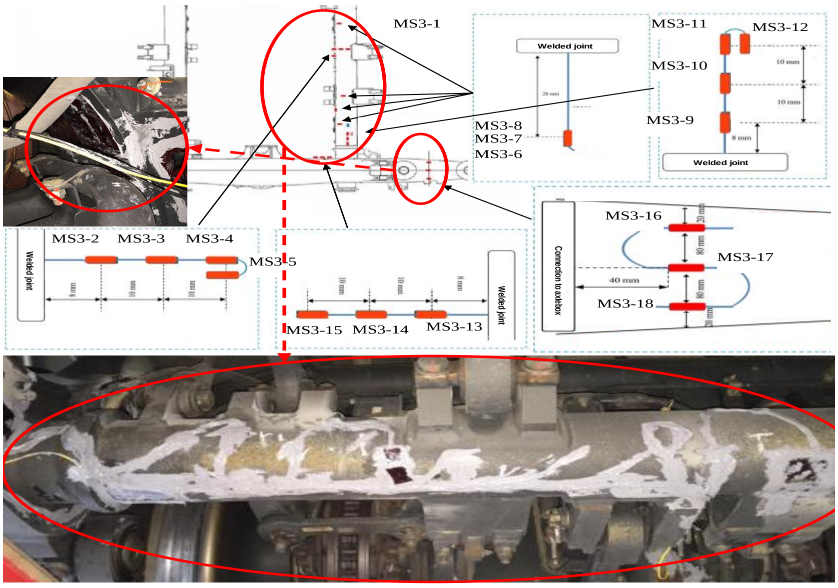


Figure 3.67 Location of sensors deployed on bogie frame of in-service high-speed train

Results

- From the results of maximum cumulative Bayes factor and run length, it is found that the real time of damage occurrence is at time 36, which is well coincident with the time point of wheel lathing;
- The developed approach not only possesses the ability of real-time automated structural health diagnosis, but also achieves damage quantification and uncertainty assessment.

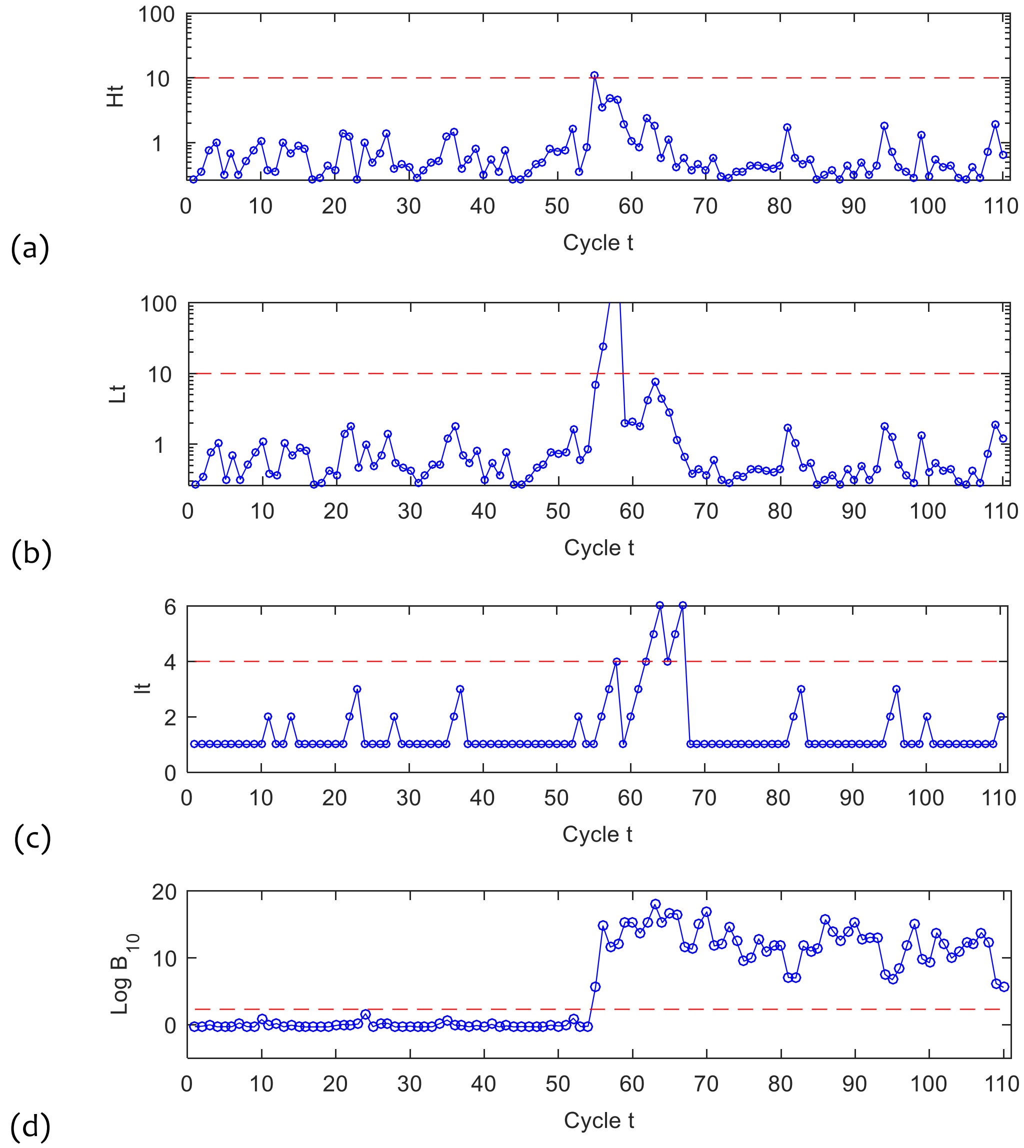


Figure 3.68 Detection results of Case 1: (a) Bayes factor; (b) Maximal cumulative Bayes factor; (c) Run length; and (d) Bayesian hypothesis testing

3.2.8 High-Speed Rail Damage Detection of Wheels Based on Convolutional Neural Networks

Motivation

Monitoring techniques have been implemented for detecting wheel defects of HSR, with the objective of generating extensive monitoring data. It is time-consuming and tedious to process and analyze the massive data using a conventional method, and sometimes even not possible. There is an urgent need for a diagnosis approach which can both efficiently interpret the massive data and automatically detect wheel damage. This study aims to solve this problem and propose an advanced machine learning based framework which employs convolutional neural networks (CNNs) deep learning for automatic feature extraction and damage detection. The advantage of this approach is its requirement of fewer computations due to the sparsely connected neurons and the pooling process.

Onboard Monitoring of the High-Speed Train

CNERC-Rail was authorized to monitor the vibration response of an operating train on the Lanzhou-Urumqi HSR Line. The vibration of the bogie and car body during routine operation were monitored before and after the wheel lathing. The monitored bogies were located in axles 5, 7, and axle 8 of Car 3 and axle 6 of Car 4. The accelerometers were installed at the frame, vertical-stop component and axle box (Figure 3.69) with the range of ± 1000 g, and the sampling frequency is 5000 Hz.

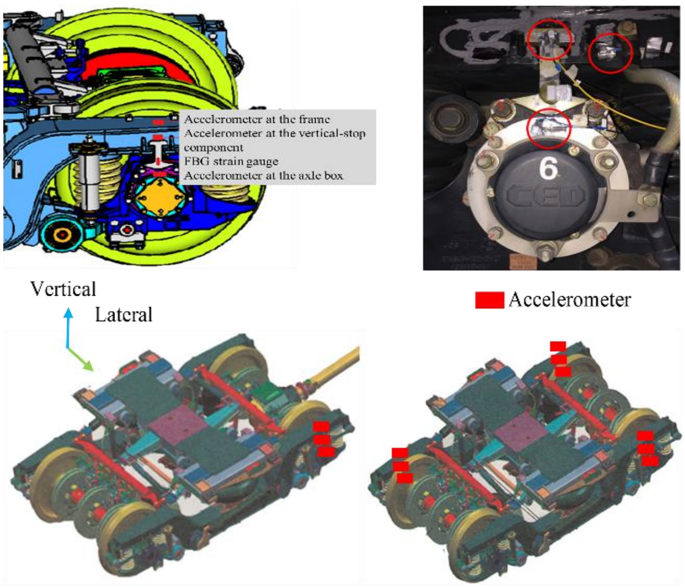


Figure 3.69 Location of the accelerometers

CNNs Framework for Wheel Damage Detection

As shown in Figure 3.70, the CNNs layer structure designed in this study includes mainly input, convolution (represented by C_i), pooling (represented by P_i), dropout layer and output layers. Some auxiliary layers such as batch normalization layers will also be implemented. The first layer is the input of raw image with a high resolution. The three image dimensions respectively represent width, height and channel. The data size will be reduced to be $1 \times 1 \times n$ at L_k (Layer k) after the raw image passes the CNNs. The new n-element vector will be fed into ReLU (rectified linear unit) layer. After a convolution layer C_{m+1}, the Softmax layer will identify the wheel damage type and damage level.

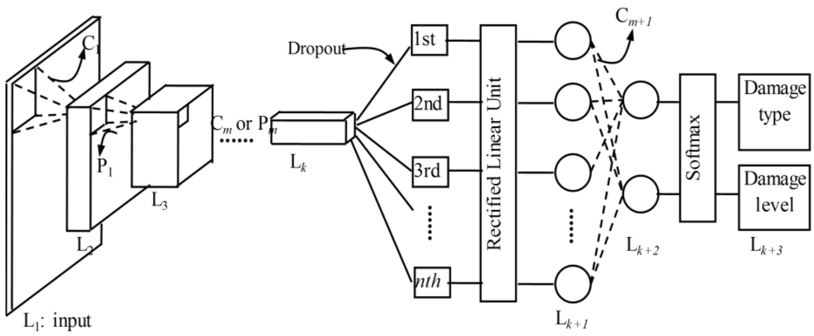


Figure 3.70 CNNs architecture

The outline of CNNs for wheel damage detection is shown in the flowchart below. It includes training and testing processes. For CNN network training, the time series vibration response is encoded as the Gramian image, which will be taken as the direct input of CNNs. The Gramian images were labeled for two categories, namely "damage" and "intact". According to the railway line conditions (e.g. train across bridge, tunnel, etc.), operating conditions (different train speeds) and operating time, the vibration data were further attached with different labels and transferred into the Gramian Angular Field for CNNs training. The raw images are chosen randomly to generate training and validation sets from the databank. After the CNNs classifier is validated, new images are scanned by the classifier to detect wheel defects. Due to a full consideration of the diversity of the vibration data in the training process, the prediction model can further determine different train operation states, a feature which can avoid the misjudgment of wheel damage and increase the robustness of the prediction model.

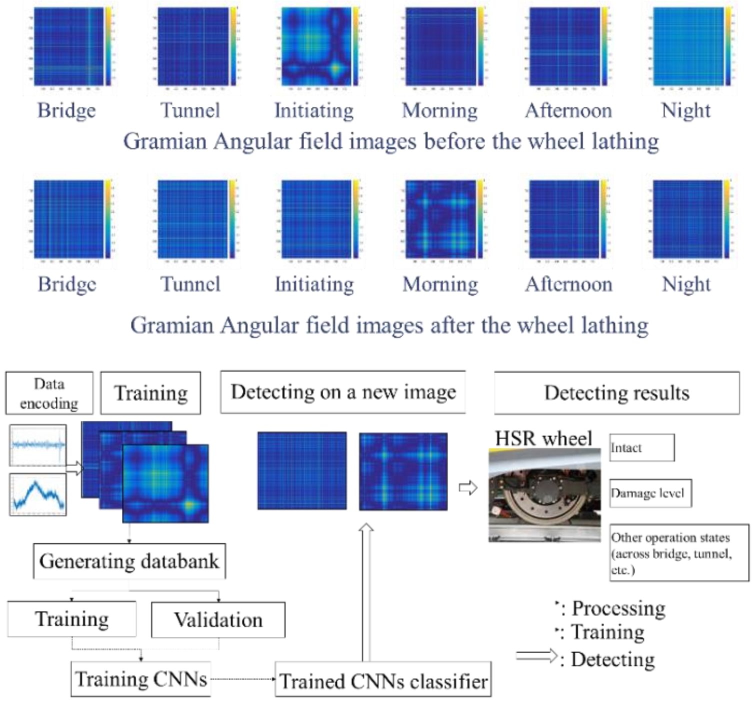


Figure 3.71 CNNs flowchart for wheel damage detection

3.2.9 GNSS-Based Ionosphere Observation of Fast-Moving Trains (GIOFT)

Motivation

The ionosphere is a major constituent of the atmosphere within the altitude 60 km above the earth surface to around 2000 km, even higher in some regions or during some extreme space weather days. Ionosphere plays a critical role in the radio-based satellite navigation and communication because of its disperse characteristic. Radio signals are refracted while travelling through the ionosphere. Global Navigation Satellite Systems (GNSS) are a powerful technique for ionosphere observations because multiple signals can be tracked from a large number of GNSS satellites. Though many ground-based GNSS stations have been deployed in China and worldwide, the ionosphere observation coverage is still limited. The fast-moving trains, including the high-speed trains, are an ideal platform for GNSS-based ionosphere observations because of a nationwide coverage. Thus an unprecedentedly high spatial resolution can be achieved. The big science data from the train-based GNSS ionosphere observation, complementing the space-based satellite observations and other ground facilities, are expected to make a significant contribution to ionosphere science studies.

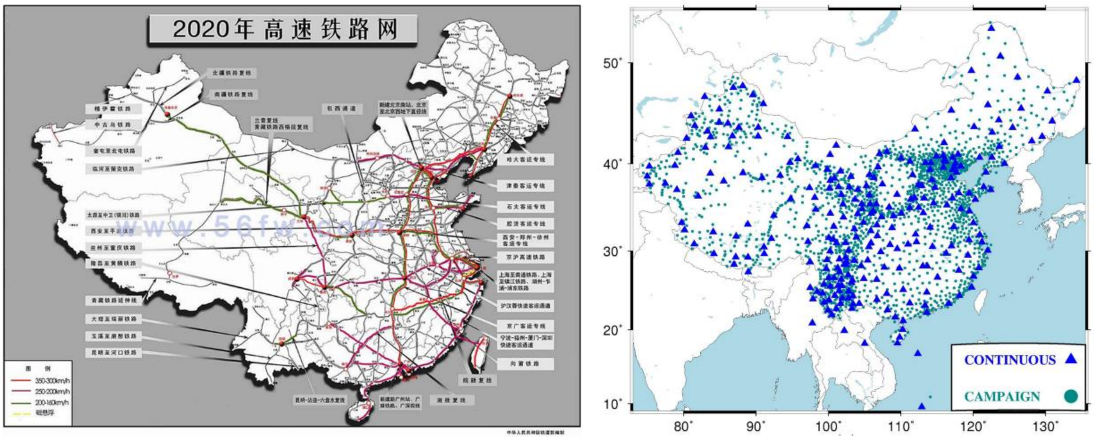


Figure 3.72 (a) High-speed railway network by 2020; and (b) Locations of ground-based GNSS stations

<u>Field Experiment</u>

To assess the TECR values between the fast-moving and stationary platforms, the GNSS including GPS, GLONASS, GALILEO and Beidou observations were simultaneously collected on the two platforms with the same type of GNSS receivers (Trimble R10) 1.5 hours. The Hong Kong Mass Transit Railway (MTR) train operating between the Shek Mun Station and the Tai Shui Hang Station, with a length of 3.1 km, was selected as the fast-moving platform. The stationary station was deployed 50 m away from the middle of the MTR route. The satellite signal cutoff elevation angle, was set to zero and the sample rate was set to 20 Hz. The dataset was separated into 6 portions as the train had stops at 6 stations. The field experiment and GNSS receiver setting at the fast-moving and stationary platforms are illustrated below.

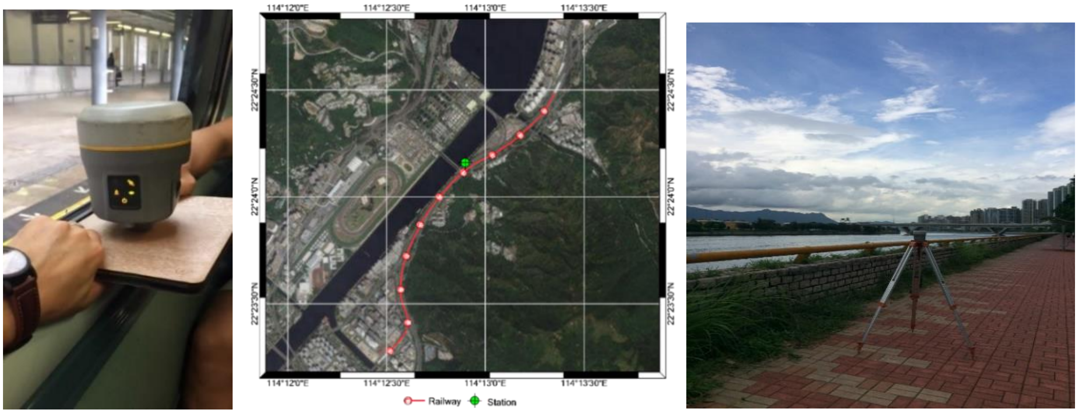


Figure 3.73 The GNSS receiver setting and spatial distribution of the MTR railway. (a) the GNSS receiver deployed in the train; (b) the railway location and stationary GNSS receiver. The red line details the MTR railway route and the green circle with a cross is the stationary receiver; and (c) the stationary GNSS receiver

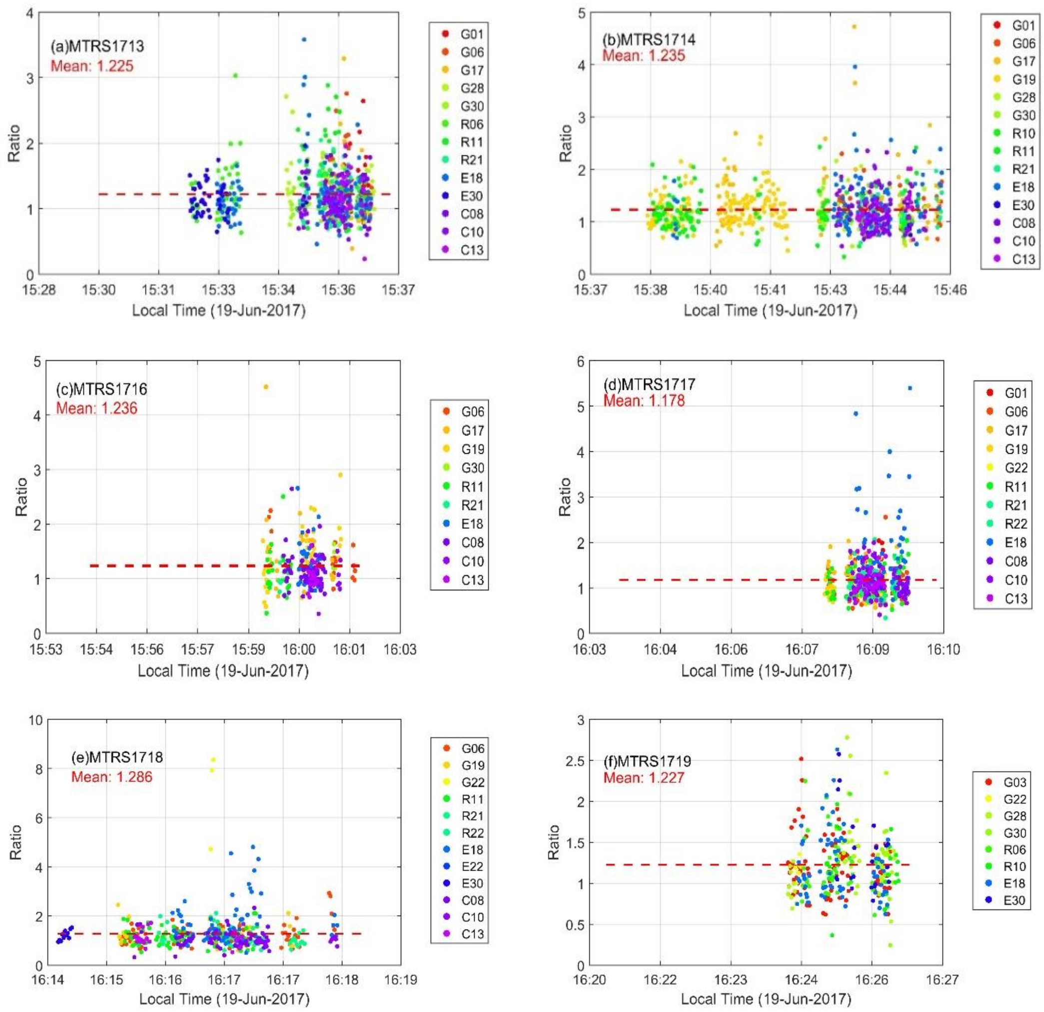


Figure 3.74 The ratio between the RMS of the TECR values from two different platforms. Every point represents the RMS ratio for a 1-second sample observation, calculated from 20-Hze raw data

Conclusions

- The fast-moving train-based TECR has a RMS ~20% larger than that of the stationary station-based TECR. This is due to the special GNSS setting inside the MTR train cabin and also due to the slightly different GNSS signal propagation paths;
- The respective increase in the level for every satellite constellation is 23%, 13%, 37% and 11% for GPS, GLONASS, GALILEO and Beidou.

3.2.10 High-Speed Rail Condition Monitoring by Compressive Sensing-Based Data Acquisition

Motivation

The knowledge of track and wheel conditions is critical for timely inspection and maintenance in order to ensure the operation safety of railway systems. In recent years, the condition monitoring for HSR based on in-service vehicles has attracted many researchers' interests because this approach can collect continuous and comprehensive data and benefit the inspection of the whole railway system. In the condition monitoring system for HSR, the sampling frequency is typically high, reaching several thousand Hz. In such a case, it is hard to simultaneously achieve adequate information captured, moderate data transferred and simple data compression or analysis at the sensor end. Fortunately, this challenge can be handled by an emerging technique named Compressive Sensing (CS) developed during the past decade.

Introduction to CS

Basically, CS combines sampling and compression in one step and directly obtains the compressed measurements y. Although recovering the original signal f from y, the basic problem of CS, is underdetermined, f can be exactly recovered exactly, by solving a basis pursuit problem under favorable conditions. Successful signal reconstruction can be asserted if a signal is sparse or compressible or when transferred to other domains.

Application and Results

The process of CS-based data acquisition is simulated using the bogie and axle box vibration data collected from an in-service train running on a section of high-speed railway in China.

Typical reconstruction results are shown in Figures 3.75 and 3.76, representing the cases that the compression ratio is about 50% and the reconstruction error is about 0.2 and 0.4. The upper panel shows random samples collected from the target signal while the lower part illustrates the reconstructed signal, which can be observed consistent well with the target one, even when the reconstruction error is 0.4.

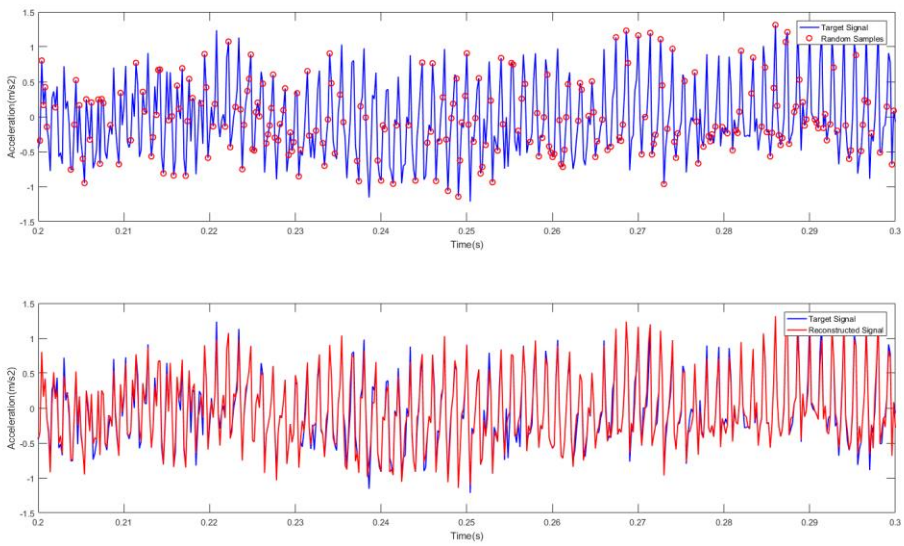


Figure 3.75 Random samples and reconstructed signal versus target signal (error = 0.2)

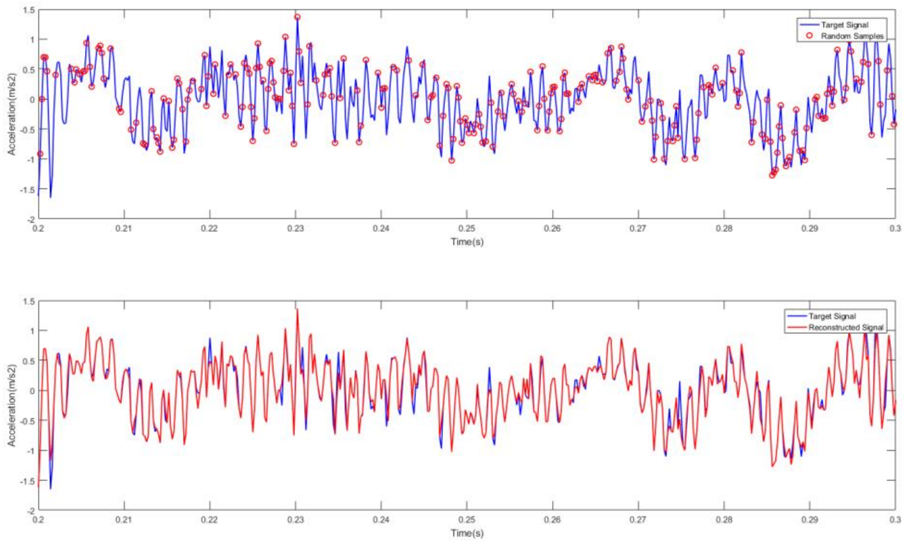


Figure 3.76 Random samples and reconstructed signal versus target signal (error = 0.4)

The vibration data were collected in two scenarios. In the first scenario, the wheels were suffering from certain out-of-roundness (OOR). A lathering process was then conducted, and the wheel's poor condition neutralized. A convolutional neural network (CNN) model was trained to identify the wheel condition based on the vibration data images. The recovery influence error to OOR identification accuracy was investigated and summarized in Table 3.2. It is shown that missing half of the samples leads only to a 1.8% drop of OOR identification accuracy.

Table 3.2 Influence of reconstruction error to OOR identification accuracy

	Testing number	Compression ratio	OOR identification accuracy
Original data	2196	100%	98.2%
RSS = 0.2	2196	76.2%	98.0%
RSS = 0.3	2196	61.2%	97.2%
RSS = 0.4	2196	48.0%	96.4%

3.3 Vibration Mitigation and Vibration Energy Harvesting

3.3.1 Full-Scale Experimental Verification of HSR Vibration Mitigation When Using Semi-Active MR-Dampers

3.3.2 Vibration Mitigation and Durability Optimization of High-Speed Train Frame Bump-Stops

3.3.3 High-Speed Train Vibration Suppression Using Negative Stiffnes Dampers

3.3.4 3D Printing Structured Rail Damper Utilizing a Metallic or Non-Metallic 3D-Structure Insert to Reduce Noise and Vibration

3.3.5 Multi-Directional Tuned Mass Dampers for Track Vibration Absorption and Noise Reduction

3.3.6 Nonlinear Energy Harvesting Systems: Theory, Methods and Railway System Applications

3.3.7 A Nonlinear Multi-Stable Piezomagnetoelastic Harvester Array for Low-Intensity, Low-Frequency, and Broadband Vibrations

3.3.1 Full-Scale Experimental Verification of HSR Vibration Mitigation When Using Semi-Active MR-Dampers

Motivation

Recently, some semi-active suspension systems have been put into practice in the railway industry, to improve both ride comfort and train stability. Among these systems, MR-dampers ensure there are no semi-active negative suspension systems in the train. However, it is essential to evaluate the MR-damper effects on other parts of the vehicle. Unlike passive dampers, dynamic parameters of MR-dampers are altered by adjusting the input current of those dampers. These alterations affect the dynamic response of the entire vehicle, especially the bogies, and this negative activity should be considered when designing the MR-damper mechanical properties, the MR-damper control algorithms, and the bogies. It is important to maintain the dynamic stability of the vehicle when parameters, of the dynamic system are known to be uncertain, and vary continuously. From this safety view point, bogies' detailed response consideration during train operations is necessary, and particularly in the case of high-speed trains. In this study, the dynamic response of bogies is studied and the interaction of the MR-dampers with the bogies is experimentally evaluated.

Test Setup

A unique comprehensive full-scale roller test was conducted on the high-speed train model CRH3. The test was carried out using the roller test rig of the State Key Laboratory of Traction Power at the Southwest Jiaotong University in China. The MR-dampers were installed in the secondary suspension system of the train, in both the leading and trailing trucks, replacing existing passive hydraulic dampers. The dynamic responses of different bogie segments were collected through a displacement network and acceleration sensors. The dynamic responses of bogies were analyzed in time-domain and frequency-domain and the interaction of MR-dampers with different segments of bogie was evaluated.

Figure 3.77 Full-scale roller test at the Southwest Jiaotong University

<u>Experimental design</u>

A total of four MR-dampers were installed. The dynamic behaviour of MR-dampers was adjusted using the electric current controller, connected to those dampers. The FBG accelerometers and displacement sensors were installed in the bogies, at different locations. The train ran at eight speed levels from 80 to 350 km/h, during each speed level, different input currents were applied to the MR-dampers.

Figure 3.78 (a) MR-dampers; and (b) FBG acceleration sensor

<u>Results</u>

The responses were collected from bogies both at the front and the back of the train. Within each bogie, three different locations were considered: the bogie center frame, the bogie side frame at the middle, and the bogie side frame above the axle boxes.

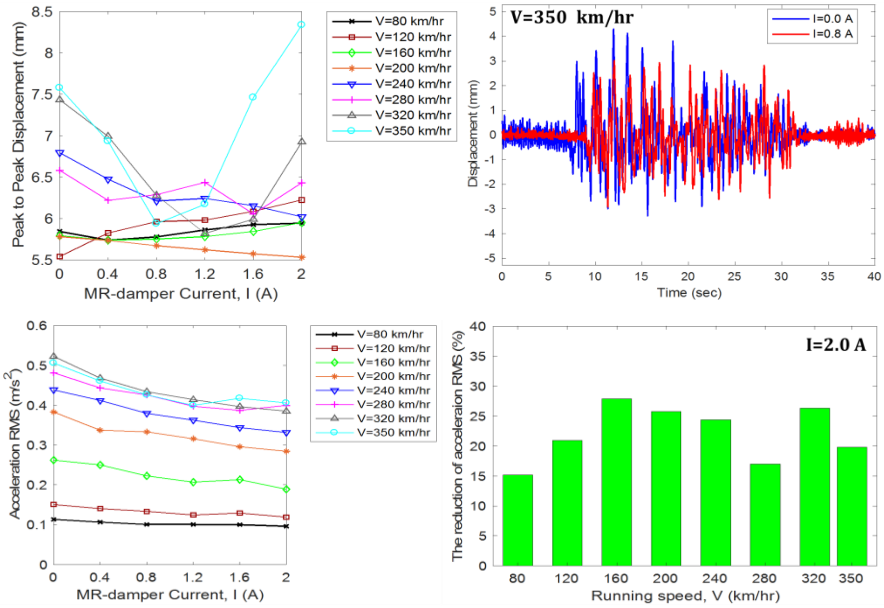


Figure 3.79 Lateral displacement and acceleration responses

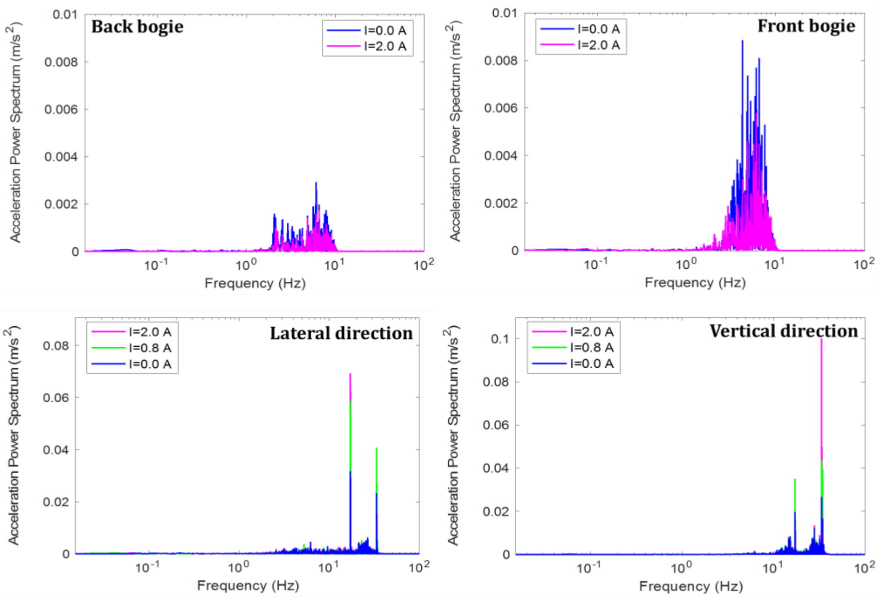


Figure 3.80 Acceleration power spectrum

Conclusions

- The MR-dampers interact positively with the bogie center frame and improve the lateral displacement response of that frame when the MR-damper input current is tuned to a certain level. The MR-dampers have no effect in the vertical direction;
- The lateral acceleration responses of the side frame of the bogie (at the middle)

is effectively reduced in proportion to the input current of the MR-dampers. The interaction of MR-dampers with the bogie, however, magnifies the vertical acceleration response;

- The lateral displacement responses of the bogie side frame (above the axle boxes) are reduced in proportion to the MR-damper input current when tuned to a certain amperage. Nonetheless, both the lateral and vertical acceleration response of the bogie side frame (above the axle boxes) are magnified by increasing the input current of the MR-damper.

3.3.2 Vibration Mitigation and Durability Optimization of High-Speed Train Bogie Frame Bump-Stops

Motivation

The rapid development of high-speed railways in China has imposed great challenges on operational safety, system reliability and human comfort. These features are imperative concerns because of the demand for increasing the speed of high-speed trains. Therefore, the development of innovative technologies that aim at practical and challenging issues induced by train dynamics, and focusing on contributing to the enhancement of operational safety and quality of high-speed trains, is paramount.

In high-speed trains, bogies are the major component supporting rail vehicle bodies. They maintain the train stability on straight and curved tracks. Additionally, they minimize the impact of centrifugal forces when turning, at a high speed, on curved tracks. A suspension system of a bogie normally consists of a frame, wheelsets, axle-boxes and other mechanical accessories. Among various vehicle mechanical components, bump-stops (known as bumpers) are critical in limiting the vertical displacement of the suspension system. The following figure shows the location of the bump-stop in the bogie. Vigorous vibration is such as 500-560 Hz which is mainly due to the resonance effect during the train operation at 200 – 250 km/hr. Excessive vibration may cause cracks and fractures, which raises safety alerts. Hence, a study is conducted in this project concerning the optimization design of bump-stops to suppress and mitigate individual vigorous vibrations during the operation of trains.

Project Objectives

- To investigate the natural frequency of bump-stops under the in-service mode of high-speed trains;
- To propose a new bump-stop design to enable the prevention of the occurrence of resonance in the operation mode of high-speed trains;
- To conduct a static stress analysis of bump-stops subject to dynamic forces;
- To mitigate excessive vibration of bump-stops and enhance their durability in operation.

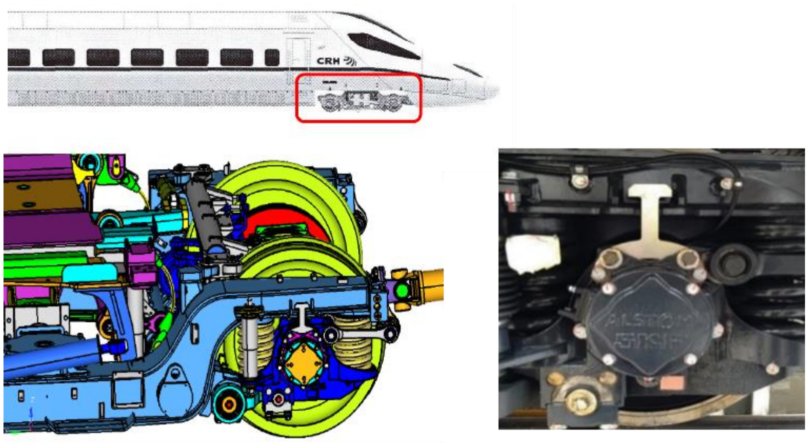


Figure 3.81 Location and configuration of bump-stop in high-speed trains

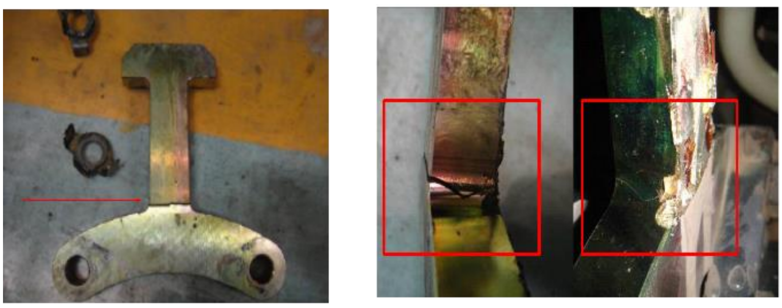


Figure 3.82 Crack on the bump-stop due to excessive vibration

Research

The investigated bump-stop is made of S355 steel and has the configuration of a bone-type structure. Due to the strict requirements, the configuration of the bump-stop cannot be altered. Hence, because of this restriction, a new idea is proposed in this project. The aim is to simply mitigate the vibration effect of the bump-stop, by adding, within the device, damping layer of adhesive material (1 mm thick) inside the device (as shown below). The function of this damping material (rubber-type material) not only can change the natural vibration frequency of the bump-stop, but also help absorb vibration energy during operations. Two different approaches are proposed to optimize the design of the original bump-stop, fully-cut and fractionally-cut versions. In these two proposed models, a 1-mm thick vertical groove was created in the middle of the bump-stop. Rubber-type gel sealants were injected into the groove to act as an absorbent layer. Both on-board monitoring tests and finite element analysis were conducted for comparison of the methods. The on-board and computational test results showed that when compared to the original bump-stop, the vibration behaviour of the newly designed bump-stop had significantly changed.

Conclusions

In this project, two newly designed bump-stops are proposed and developed to avoid the occurrence of resonance during the train operations. Additionally, a universal concept for an optimization design of bump-stops in various types of high-speed trains, is presented.

Figure 3.83 Newly designed bump-stop and on-board monitoring test installation

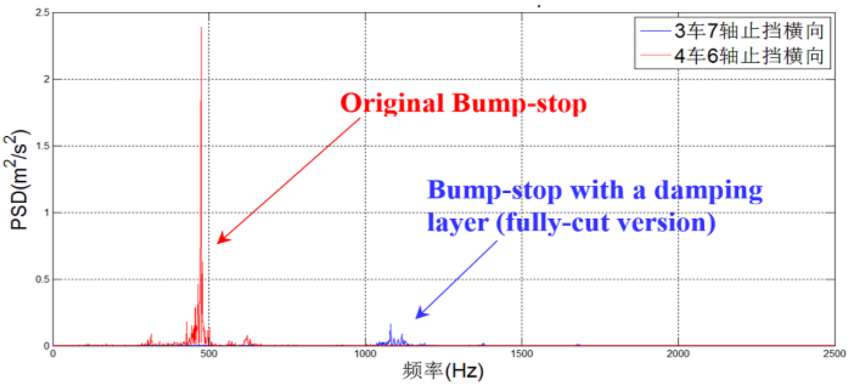


Figure 3.84 On-board monitoring test results

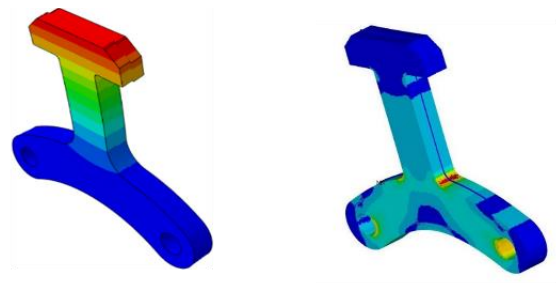


Figure 3.85 Finite element models for static and dynamic analysis

3.3.3 High-Speed Train Vibration Suppression Using Negative Stiffness Dampers

Benefit of Negative Stiffness in Vibration Control

Active control based on the linear quadratic regulator (LQR) algorithm, a commonly adopted optimal control theory, may produce a damper force-deformation relationship with an apparent negative stiffness feature that benefits control performance. This finding has inspired the exploration of a passive negative stiffness damper (NSD) that produces similar hysteresis and achieves control performance, comparable to that of active dampers. Negative stiffness has been proven to be beneficial in many vibration control applications, including buildings, stay cables, isolation tables and so on. However, the effectiveness of NSDs in high-speed train suspensions has not been systematically examined. The work presented in this study, indicates the benefits of negative stiffness behavior in vibration control for high-speed trains.

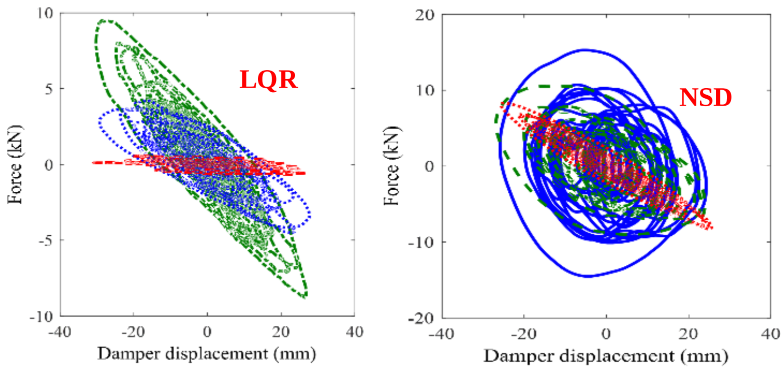


Figure 3.86 Relationship between damper force and displacement

Magnetic Negative Stiffness Damper (MNSD)

MNSDs are based on a magnetism principle, completely distinct from existing negative stiffness configurations. The MNSD is a fully passive damper that efficiently integrates the negative stiffness mechanism and eddy-current damping in a compact and simple configuration. The compact design widens the application of an MNSD and makes it applicable to various civil and mechanical structures.

Two types of MNSD, namely MNSD-A and MNSD-B, are proposed in this study (as shown in the figure below). In MNSD-A, stiffness becomes stronger during larger displacements of moving magnets; while in contrast, in MNSD-B, stiffness becomes weaker during the larger displacements of moving magnets.

The negative stiffness can be controlled by designing magnet arrangements, dimensions and strength. In this study, the numerical model for MNSDs has been developed. The effects of magnet arrangement and dimensions on the negative stiffness and eddy-current damping characteristics are systematically investigated through parametric studies. The MNSDs are also individually optimized to maximize the negative stiffness and eddy-current damping coefficients. Based on the optimization results, some optimal design formulas have been developed to facilitate the quick design of MNSDs for different future vibration suppression applications.

Application in High-Speed Trains

The model with 17 degrees of freedom (DOF) for high-speed trains is adopted for numerical simulations. The high-speed train model is composed of one car body, two bogies, and four wheelsets. In the secondary suspension, the car body in the lateral direction, because the secondary lateral damping is the most critical element of a car body in terms of vibration suppression. To verify the benefits of negative stiffness, the performance of the LQR controller for high-speed trains is also investigated.

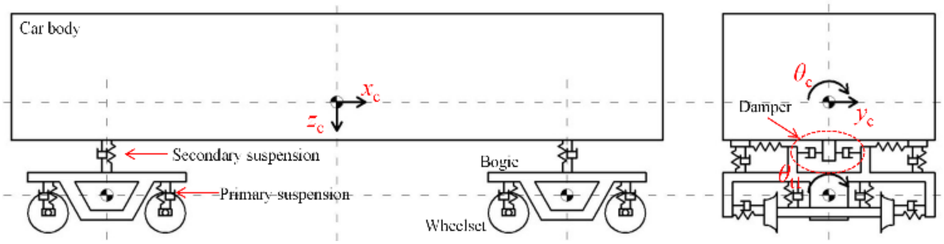


Figure 3.87 High-speed trains model with 17 degrees of freedom

All the car body responses in the lateral, yaw, and toll directions decrease as the strength of the negative stiffness, increases from −105 kN/m to −315 kN/m. Similar conclusions are drawn from the car body response in the frequency domain. The peak PSD responses in the lateral, yaw, and roll directions decrease as the strength of the negative stiffness increases.

As shown in the figures below, the passive MNSD can achieve comparable performances of the active controller. It is also be pointed out that the simulation results of the high-speed train with the active LQR controller can be considered the ideal. In practice, the sensing noise and the feedback delay may considerably degrade the LQR controller performance. However, the passive NSD is immune to such adverse effects.

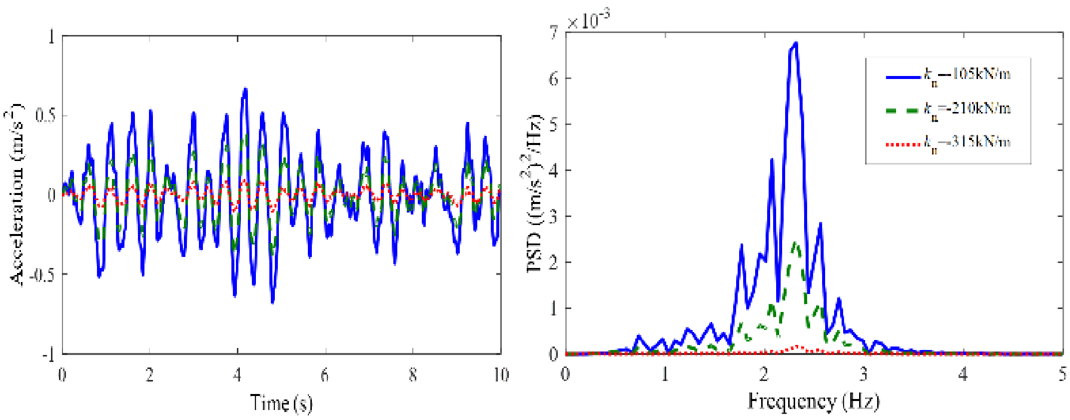


Figure 3.88 Performance of NSD: (a) Time history of car body acceleration in lateral direction; and (b) PSD

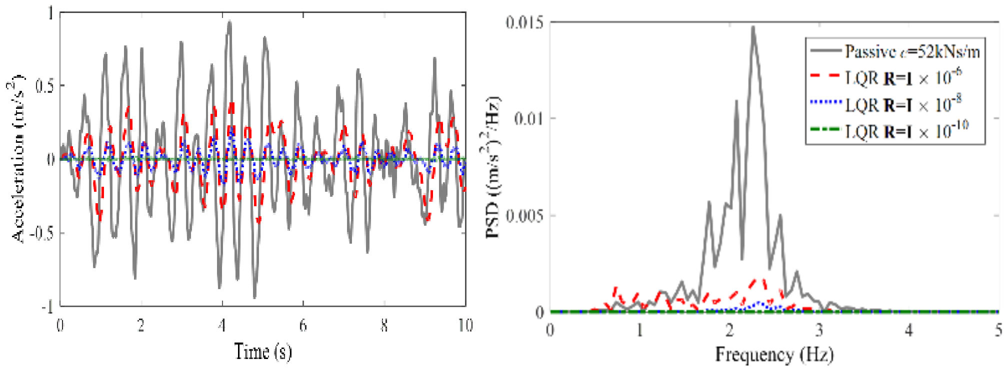


Figure 3.89 Performance of LQR: (a) Time history of car body acceleration in lateral direction; and (b) PSD

3.3.4 3D Printing Structured Rail Damper Utilizing a Metallic or Non-Metallic 3D-Structure Insert to Reduce Noise and Vibration

The most important source of environmental noise from railway operations in most situations is rolling noise. Reduction of noise at the source can be considerably more cost-effective than constructing noise barriers.

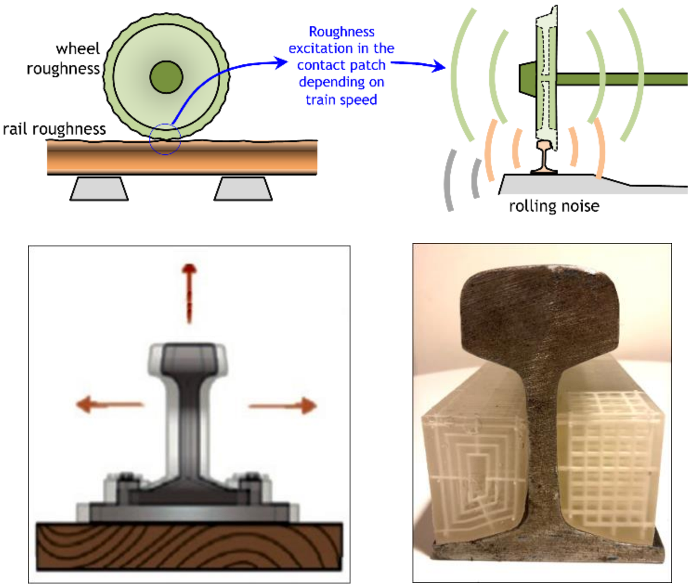


Figure 3.90 3D printing damper model attached on railway

A structured rail damper is an innovative idea to strengthen the conventional elastomeric rail damper by utilizing a metallic 3D-insert structure insert, hence enabling increase in both the stiffness and damping of the conventional rail damper.

Using different 3D-insert structure in one single damper creates a multi-functional option, suitable for use in different vibration frequencies.

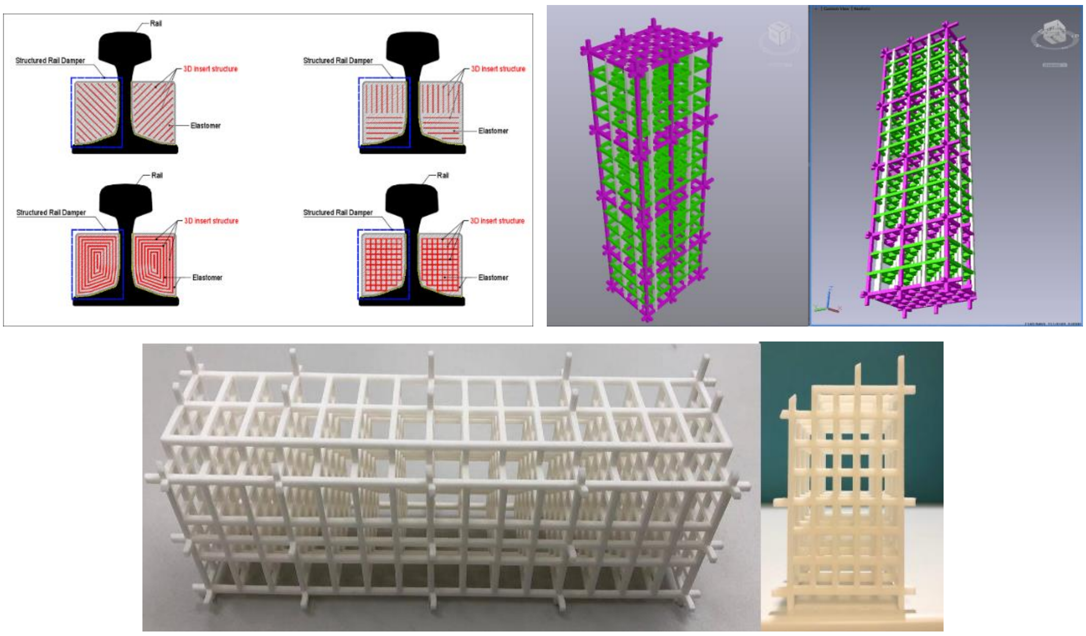


Figure 3.91 3D printing-insert structures

3D printing-insert structure

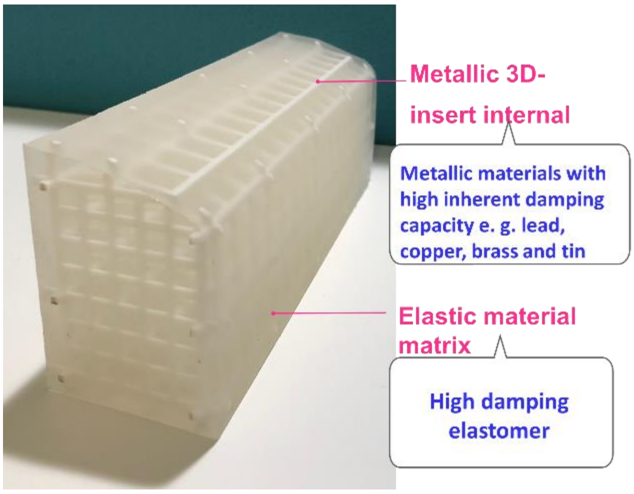


Figure 3.92 3D printing damper model

Main Advantages of the Structured Rail Damper

- The use of 3D printing technology to fabricate a 3D-insert structure for dampers by using a variety of metallic and non-metallic materials;
- The capability of fabricating 3D-inserts with various structural arrangements by using 3D printing technology to enhance rail damper stiffness a wider frequency rail vibration ranges;
- The enhancement of damper damping ability by utilizing three different energy, forms already present in the damper.

3.3.5 Multi-Directional Tuned Mass Dampers for Track Vibration Absorption and Noise Reduction

Advantages

- Absorption of rail vibration (wheel / rail interaction on rough surfaces);
- The Retrofitting of normally, only target 2 to 4dB(a) noise reduction;
- Usefulness when other noise control measures are not allowed.

Figure 3.93 Saloon noise reduction through installation of a rail damper section

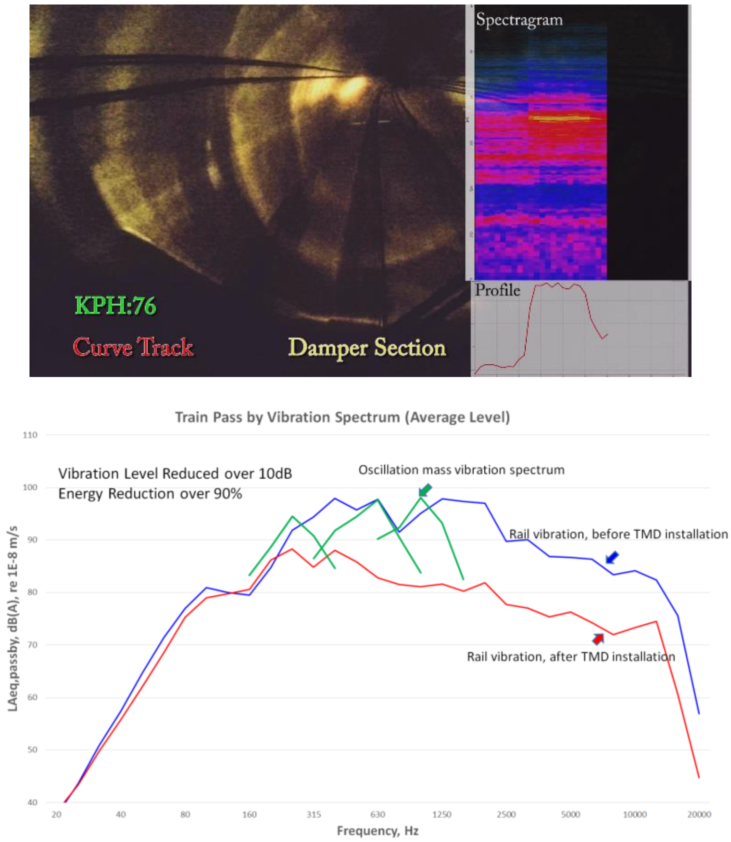


Figure 3.94 Rail vibration comparison before and after TMD installation

Corrugation Growth Suppression by Rail Dampers

Some types of short-pitch rail corrugation (~30mm to 100mm) are generated due to pin-pin rail resonance, where stick-slip at the wheel/rail interface occurs at the same frequency. Rail damper can not only suppress rail resonance, but also suppress corrugation growth. It is observed on a few sites that the rail dampers significantly reduce the corrugation growth rate for short-pitch corrugations at low rail. Grinding removes corrugations but introduces slight grinding marks, which would temporarily increase rail noise. A normal grinding cycle leads to 5 to a 10dB(a) noise variation.

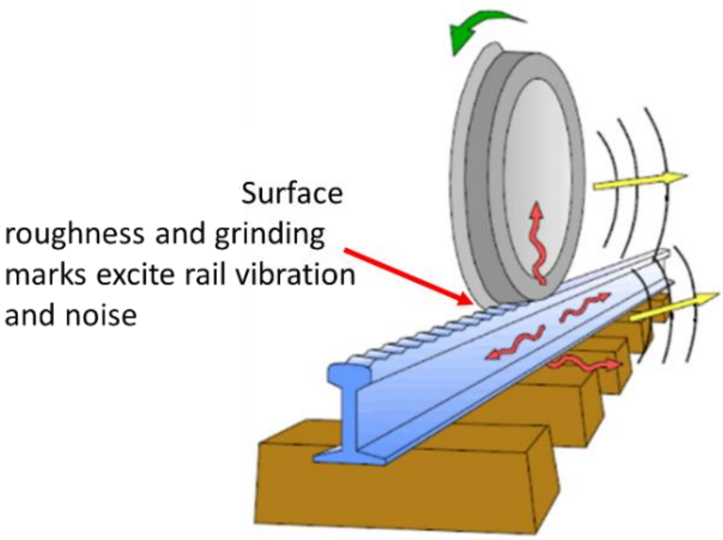


Figure 3.95 Surface roughness and grinding marks excite rail vibration and noise

Highly Effective Tuned Mass Damping

- Absorber movement is an anti-phase (180 degree phase lag) at high frequency;
- Energy is dissipated by hysteresis in the relative movement.

Figure 3.96 (a) Slight corrugation with railway damper; and (b) Significant corrugation at the section adjacent to the damper section

3.3.6 Nonlinear Energy Harvesting Systems: Theory, Methods and Railway System Applications

Motivation

Vibration issues extensively exist in various engineering practices and in most cases are disturbing to passengers. Vibration energy can be employed, stored and hence suppressed. Thus, vibration energy harvesting systems have been the focus of great attention for many years, and with it the realization that such “noise” can be converted from vibration energy into electrical energy. The main energy conversion mechanisms are based on electromagnetic and piezoelectric transduction. Initially, linear vibration energy devices are designed for harvesting vibration energy nearby the resonant frequency. The energy harvesting performance, however, will be dramatically reduced, as the base excitation frequency shifts. Sensitive vibration in human life or engineering systems, such as railway noise is often located in the low frequency range, hence it is not only challenging, but important to design an efficient vibration energy harvesting system performance in the low frequency range and/or covering wider band widths. Hence, the aims of this study are:

- To investigate beneficial nonlinearity for improving vibration energy harvesting efficiency at low frequency;
- To investigate a novel structural design for achieving beneficial nonlinearity;
- To develop novel vibration energy harvesting systems which can power sensor networks for structural health monitoring.

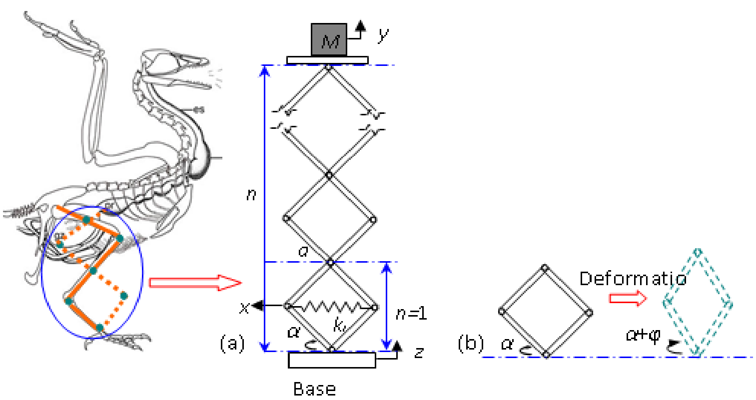


Figure 3.97 The bio-inspired limb-like structure

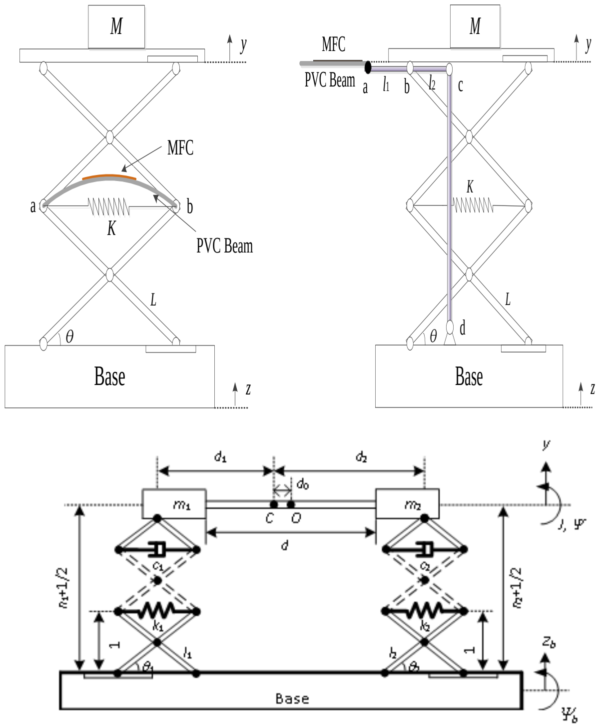


Figure 3.98 Different prototype designs aimed to achieve adjustable quasi-zero stiffness, nonlinear damping and nonlinear inertia of different sizes

Research Work

Vibration energy harvesting systems via an X-structure coupled with piezoelectric patches of special arrangements are investigated in this study. Two piezoelectric harvesters are specially installed on an X-shaped structure to explore what potential benefits the X-shaped structure is able to provide. Each piezoelectric pad has two layers composed of a PVC (Polyvinyl chloride) base patch and a MFC (Micro fiber composite) patch. The theoretical analysis and experiment results indicate that the energy harvesting performance of the proposed novel arrangements of the piezoelectric harvesters can be enhanced especially in low-frequency ranges (below 10Hz), compared with conventional cantilevered piezoelectric harvesters. More and higher energy harvesting peaks can be developed and the effective harvesting frequency band can obviously be enlarged by expansion to a low-frequency range by means of the proposed methods. The X-structure based generators can enable piezoelectric materials to harvest power from low-frequency vibration sources due to the advantages of its ability to design equivalent nonlinear stiffness, the latter being able to be easily tuned by adjusting the key structural parameters. The design and results would provide an innovative solution and insight for smart piezoelectric materials to improve the energy harvesting efficiency in low-frequency ranges including such as small-scale ocean wave power harvesting, human motion power and animal kinetic power harvesting.

Significance

In this project, a bio-inspired limb-like structure which can achieve adjustable stiffness, damping and inertia for achieving much better energy harvesting efficiency at the low frequency range, is employed in the design of novel vibration energy harvesting systems. Several benchmark prototypes have been systematically investigated and tested in the laboratory. Compared with traditional methods, the developed new prototypes can demonstrate higher efficiency and power output not only at low frequency but also in a broader frequency range. Hence, a solid base for further application regarding high-speed railway systems for vibration suppression and structural health monitoring is indicated as possible.

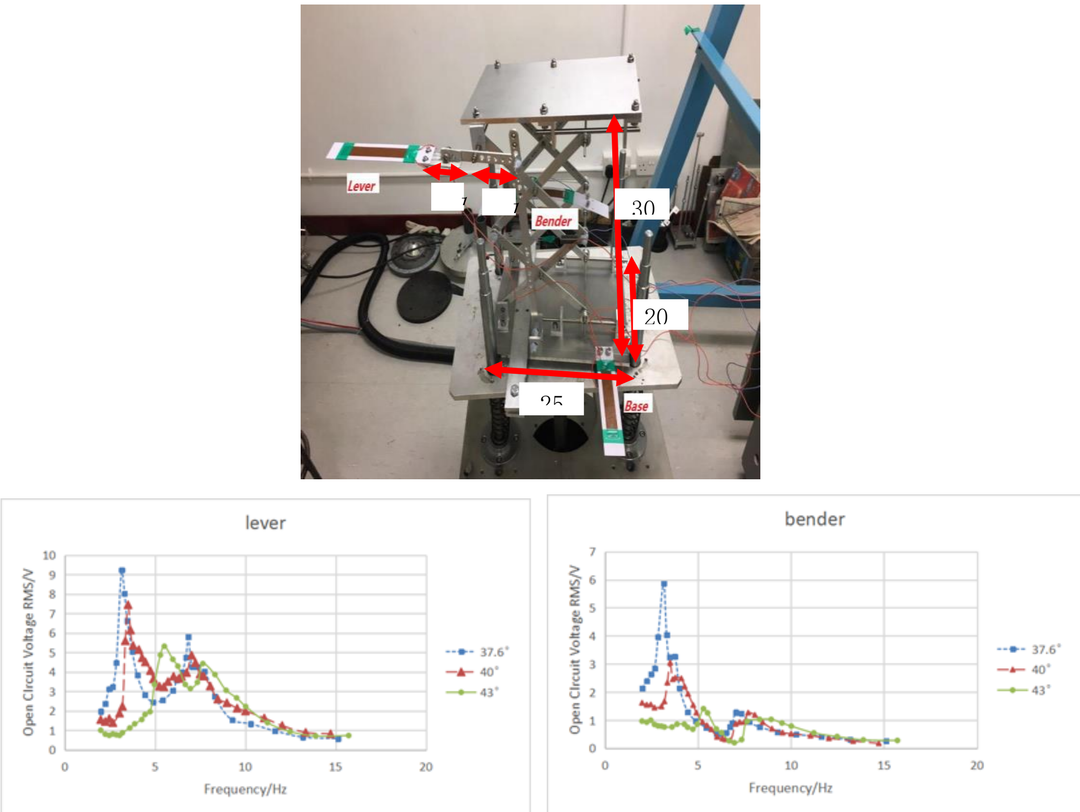


Figure 3.99 Experiments and results achieving ultra low frequency vibration energy harvesting

3.3.7 A Nonlinear Multi-Stable Piezomagnetoelastic Harvester Array for Low-Intensity, Low-Frequency, and Broadband Vibrations

Motivation

Over the past decades, energy harvesting techniques from ambient vibrations using piezoelectric materials have received significant research focus. This is mainly due to its promising applications in wireless sensor networks and portable electronic devices. Conventional linear harvesters suffer from a narrow bandwidth, and thus, are not usually practical in real-world applications due to time-variation and the random nature of most realistic ambient vibration sources. To resolve this issue, much effort, based on active and adaptive frequency-tuning schemes, has been exerted to expand the harvesters' effective bandwidth. However, a key design challenge needs to be addressed before these broadband vibration energy harvesters can be deployed in practical applications. The challenge relates to how to produce sustained and uniform large-amplitude electric responses while also maintaining high power density under low-intensity excitations. In this study, a compact multi-stable piezomagnetoelastic energy harvester array (MPEHA) is presented in an attempt to solve this important issue. The future goal is to apply the MPEHA for realization of a self-powered monitoring system on the bogie of high-speed trains.

Working Mechanism of the Multi-Stable Harvester Array

In the proposed MPEHA, the tri-stable harvesters Type A, with an approximately uniform well depth and the mono-stable harvesters Type B with a cymbal shape potential are arranged alternatively and, for compactness, share the fixed magnets. The schematic of the proposed MPEHA is shown in the figure below, where it is seen that the copper layers on the magnet tip can protect the brittle magnetic materials from mechanical impact, serve as a proof mass to change the resonant frequency, and adjust the effective distance between the adjacent harvesters, d_g.

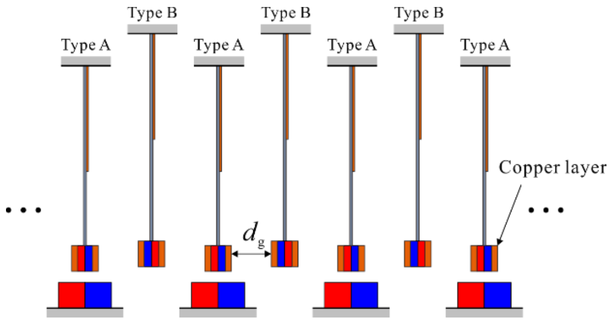


Figure 3.100 The schematic of the proposed MPEHA

The orientation of the magnetic pole in relation to tip magnets, cause a repulsion of magnetic coupling forces between the adjacent harvesters, which then depend on the relative positions of the tip magnets. This repulsion magnetic coupling force can be negligible when a relatively large distance is maintained between the adjacent harvesters during vibration. However, when the adjacent harvesters are very close to each other, the repulsive magnetic coupling force becomes significant and occupies an energy transfer role. In addition, by adjusting the effective distance d_g, impacts may occur between the adjacent harvesters. Due to the effects of the repulsion practice of the magnetic coupling force and mechanical impact, there are two main interaction modes between two adjacent harvesters, namely, under low-amplitude external excitations, as shown in the figure below.

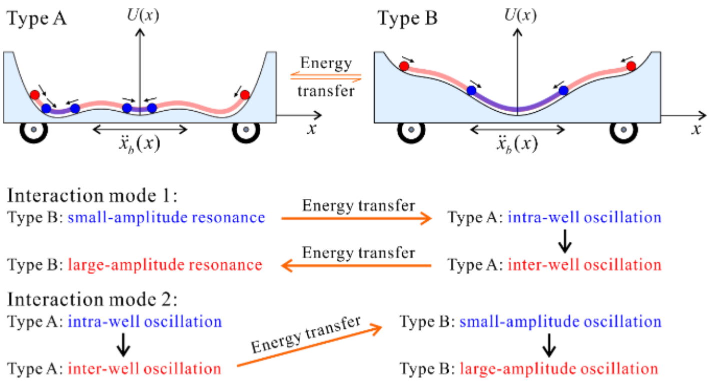


Figure 3.101 Interaction mechanism between Type A and Type B

Experimental Investigation

To show the advantages of the MPEHA, the harvesting performance of the harvester Type A, Type B and the MPEHA prototype is experimentally compared. The prototype comprises three beryllium bronze beams mounted on micro-displacement platforms. The tip magnets (NdFeB) with copper counterweights are attached to the beams as proof masses, allowing oscillation near fixed magnets mounted on a micro-displacement platform. The relative distance between the tip and fixed magnets can be adjusted by using the micro-displacement platforms. Macro-Fiber-Composite (MFC, M-2807-P2) layers are laminated near the fixed end of each of the beams for energy conversion.

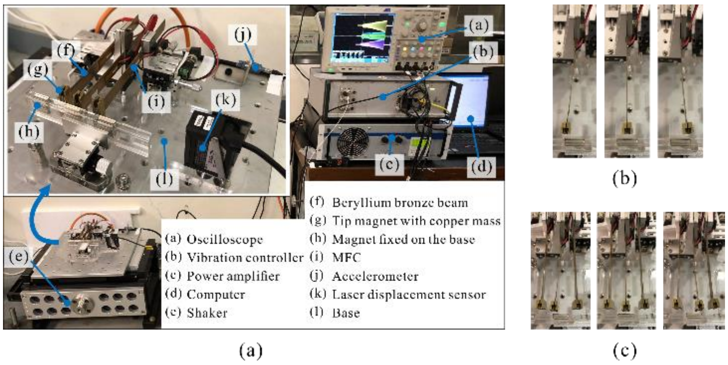


Figure 3.102 (a) Experimental setup and a close up view of the proposed MPEHA; (b) Three stable equilibrium positions of the oscillator Type A; and (c) Three stable equilibrium positions of the proposed MPEHA

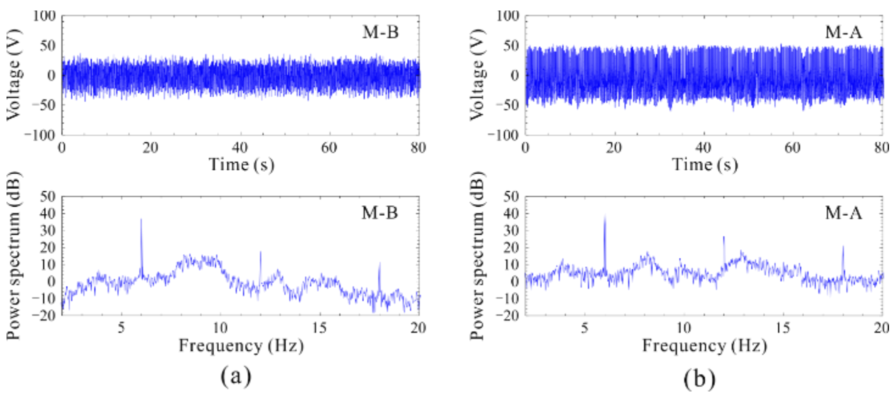


Figure 3.103 Output voltage and power spectrum at 6 Hz with acceleration level of 3 m/s^2 of (a) M-B; and (b) M-A. M-A and M-B stand for the harvesters Type A and Type B in the MPEHA, respectively

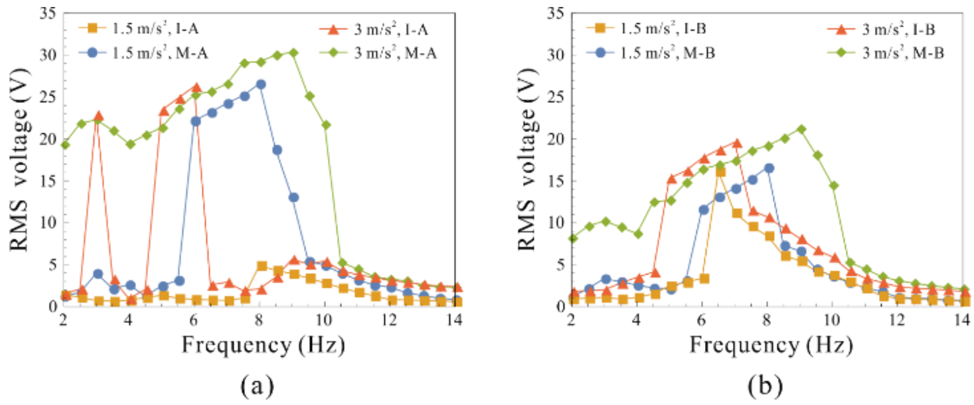


Figure 3.104 Experimental results under a constant frequency excitation for (a) Harvester Type A; and (b) Harvester Type B

3.4 Other Innovative Research Projects

3.4.1 Evaluating the Hong Kong Metro Network Route Redundancy

3.4.2 The Environmental Evaluation of Passenger Transport Spatial Agent Based Model

3.4.3 Airborne Bacterial Communities within Serviced High-Speed Rail Carriages: Diversity, Sources and Health Impacts

3.4.4 The Energy Efficiency and Global Mobile Sensing Environment Enabled by High-Speed Rail

3.4.1 Evaluation of Hong Kong Metro Network Route Redundancy

Motivation

The Hong Kong Mass Transit Railway (MTR) is one of the most profitable urban rail transit systems in the world, providing a convenient way to access most areas of the city. Latterly, frequent disruptions, has drawn public attention to what is perceived as network vulnerability. This project aims to evaluate route redundancy to combat the observed vulnerability of the Hong Kong metro network. To carry out a relevant analysis, definitions of alternative routes and a solution algorithm to calculate the travel alternative diversity are described and the top ten vulnerable stations, then identified. In addition, the proposed approach is adopted to study the impact of a new metro line, the Shatin to Central Link (SCL), to be completed in 2021. Thus, this study aims to provide insights that, most importantly could contribute to an understanding of the topology of the Hong Kong metro network and hence better enable a pre-disaster transportation system evaluation and associated planning.

Result Analysis

Using the concept of a circular metro map, the Hong Kong metro network is depicted in a ring-radial structure (Figure below). The travel alternative diversity index is used to address the route redundancy of the Hong Kong metro network. It refers to the existence of effective routes available for travelers and, also available corresponding routes to be further used as evacuation routes when disastrous events are encountered. In this study and as seen in the associated graph, it is assumed that each node is disrupted in turn, and the route diversity index in each case is shown in the figure below.

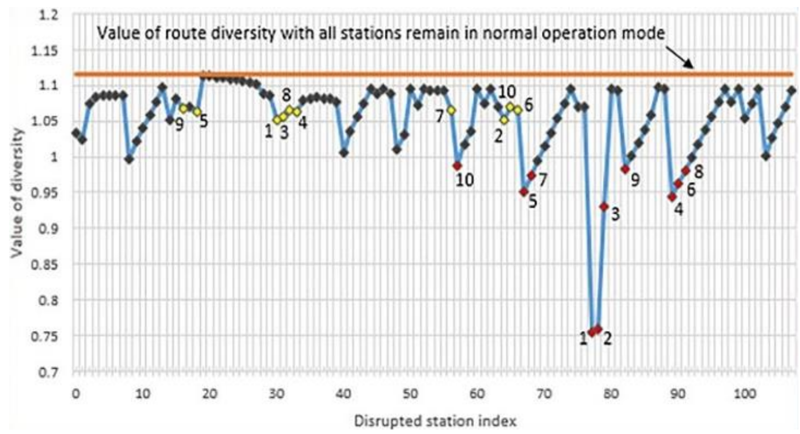


Figure 3.105 Value of the travel alternative diversity index with the station disrupted in turn

Two types of vulnerable stations are considered with the following findings: (i) The 'most vulnerable' stations are located mainly on the circumferential line, and the disruptions of these stations isolate the radial lines from the remaining network; (ii) The top ten 'relatively vulnerable' stations appear, at first glance, to be straightforward since central stations with lines passing through are typically considered as important stations; and (iii) Not all vulnerable stations are transfer stations. This indicates the possibility that station type and locations may play a role in addition to connectivity in a metro network. The overall result indicates that the diametrical line is of key importance in the network structure.

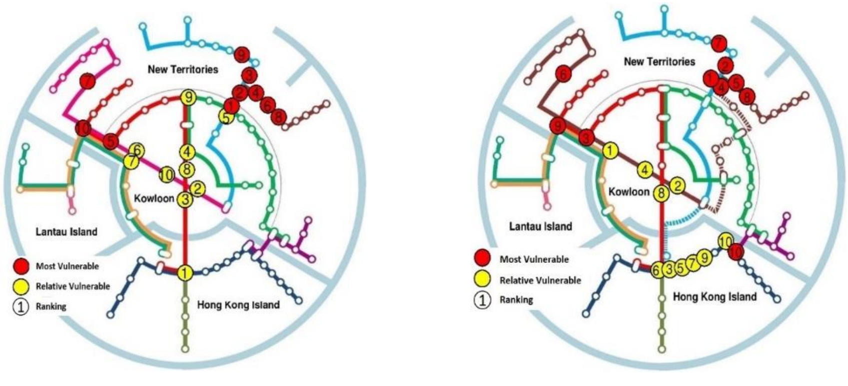


Figure 3.106 The top ten vulnerable stations in the existing network and the top ten vulnerable stations in the extended network

3.4.2 The Environment Evaluation of a Passenger Transport Spatial Agent Based Model

Motivation

This study presents an urban transportation simulation model for lifecycle environmental performance evaluation (ALENT). ALENT integrates geographic information to quantify stations' accessibility levels and construct real-world intercity transportation maps. A conceptual meta-theory from psychology is adopted to form the behavioral rules of passengers choosing different transport modes as influenced in part by passengers' social networks. Operation scenarios are simulated for the year in which Hong Kong's high-speed railway is introduced, viewed from a lifecycle assessment perspective. The simulation results suggest that the occupancy rate of the HSR should be maintained—at more than 80%—to lower the overall environmental impacts. The through train may need to be shut down to mitigate the system environmental impacts by up to 30%. ALENT can be used as a decision support tool for establishing sustainable passenger transportation systems.

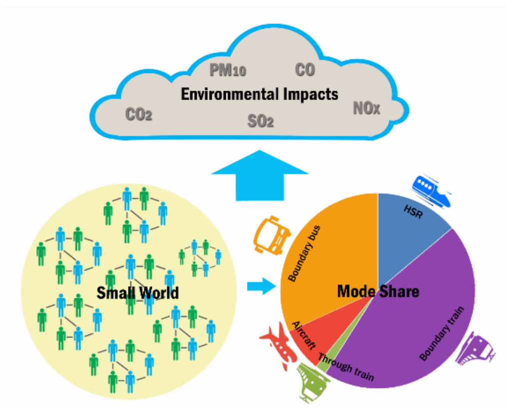


Figure 3.107 The urban transportation simulation model

The Model

This study combines agent-based modeling and life-cycle analysis to explore the environment impacts of an existing passenger Transportation system with a newly introduced HSR. The model is named as ALENT.

The Agents

ALENT comprises two kinds of entities: modes and passengers. Modes refer to those of the main intercity transport, including HSR, train, bus, and airplane. Life-cycle environmental assessment of these intercity modes is conducted taking into account. Passengers embedded in this transportation "world" have a number of "friends" who can influence their mode choices. Passenger mode choice behavior can change the mode shares of the transport modes, causing the operational and life-cycle environmental performances of this transportation "world" will be also influenced accordingly.

The Interactions among Agents

The mode choice process is shown in Figure 3.108(a). The model interface is shown in Figure 3.108 (b).

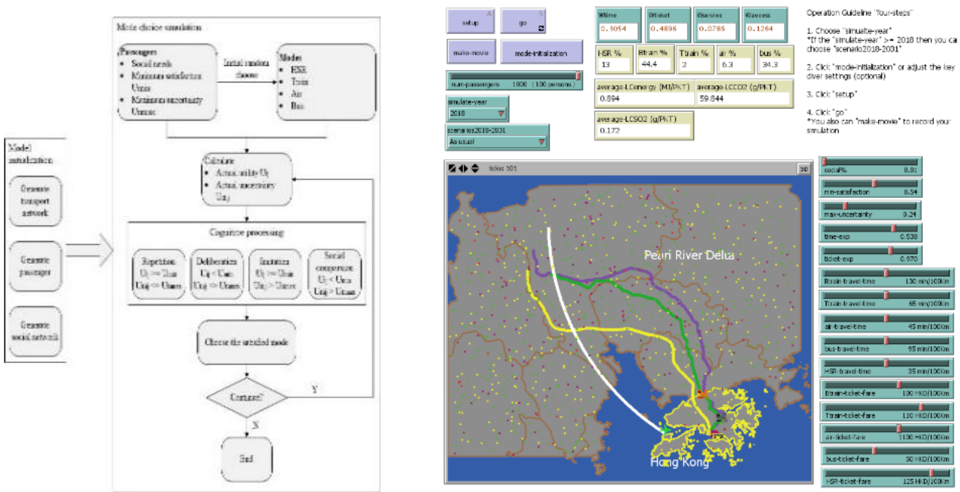
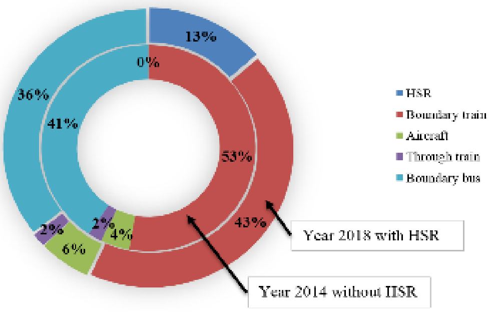


Figure 3.108 (a) The mode choice process; and (b) The model interface

Case Study

China has built the world's largest HSR network. The 26-km long Hong Kong HSR section running between West Kowloon and the Shenzhen Boundary connects with the 16,000-km national high-speed railway network. With the introduction of HSR, however, the mode shares of existing modes between Hong Kong and mainland China, including boundary train, aircraft, through train, and boundary bus, will be influenced.

The motivation of this study is to investigate how the life cycle environmental performances of existing transport systems will be affected by the introduction of HSR. In this study, the environmental performances of the HSR, boundary train, through train, aircraft, and boundary bus are evaluated based on passengers' different mode choices. Some operation strategies are proposed to minimize the environmental impacts. The model is calibrated with historical mode share data from the Cross-boundary Travel Survey 2003-2014.



Occupancy rate	2014	2018
HSR	0.00	0.78
Boundary train	0.94	0.94
Aircraft	0.82	1.24
Through train	0.67	0.66
Boundary bus	1.00	1.11

Figure 3.109 Future mode shares and occupancy rate

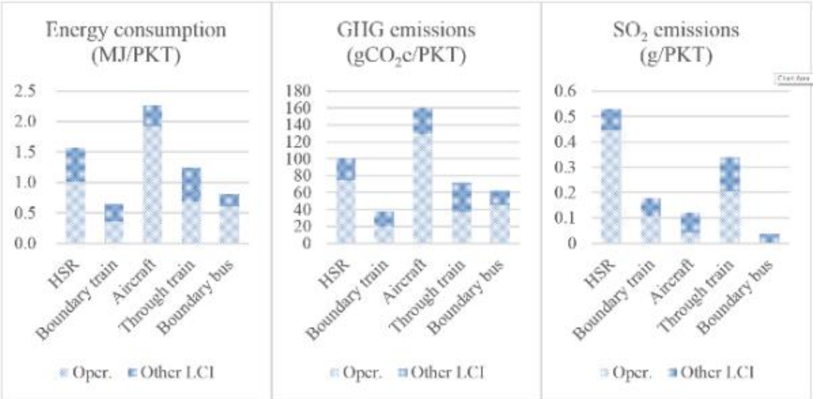


Figure 3.110 Scenarios simulation: Shutting down through the train scenario (HSR ticket fare scenario)

Conclusions

- Guangzhou-Shenzhen-Hong Kong HSR needs to sustain a high occupancy rate—more than 80%—to lower its environmental impacts;
- Shutting down the through train, which provides the same service as that of HSR, but with longer travel times, can mitigate system life-cycle environmental impacts by up to 30%;
- The boundary train may need to cut its daily frequency as its mode share decreases after 2018. In contrast, airlines will need to increase their daily flight frequencies or capacity by 2018.

3.4.3 Airborne Bacterial Communities within Serviced High-Speed Rail Carriages: Diversity, Sources and Health Impacts

Motivation

The high-speed rail can be a means of transporting infectious diseases rapidly on a local, regional, and national scale. However, our understanding of the sources and composition of airborne bacteria in serviced high-speed rail carriages is limited. Outdoor and indoor air bacterial communities are highly ephemeral and can change over short periods by high-speed rail services. Direct contributing factors can include human occupancy rates and activities, such as the frequency of toilet usage that potentially increases the airborne bacterial load and human pathogens inside the carriages. Additionally, air ventilation also influences bacterial community distribution by its operational principle. Thus, the relative connectivity between passengers and ventilation should be considered. The aforementioned questions need to be addressed to prevent passengers from health consequences due to disease-related microorganism threats.

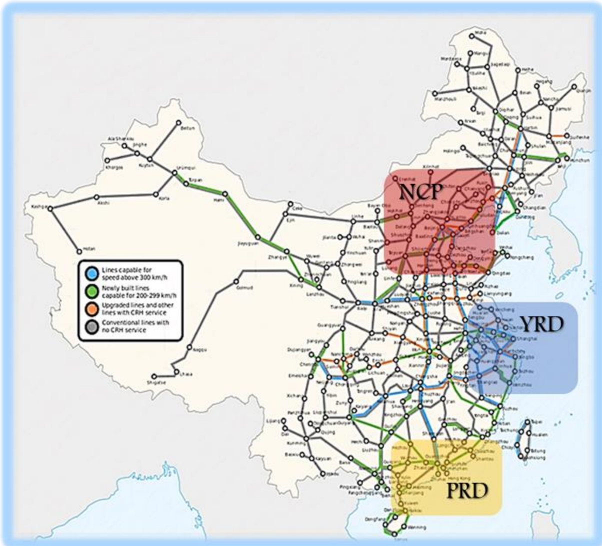


Figure 3.111 The map of high-speed rail line

Research Objectives

- To understand the driving compositions such as locations, passengers, excreta, ventilation, occupancy, outdoor air source, and the possibility of multiple transfer of disease carried by microbial communities by means of the operation modes typical during of the high-speed rail operations;
- To map the spatial distribution of microbial communities along the travel routes, and to develop comprehensive information between pathogen contents and meteorological conditions;
- To elucidate the regional/superregional transport of microbial communities, to which links between airborne and faecal pathogen distribution patterns and air pollutants to devise control strategies to further develop disease spread-out prevention.

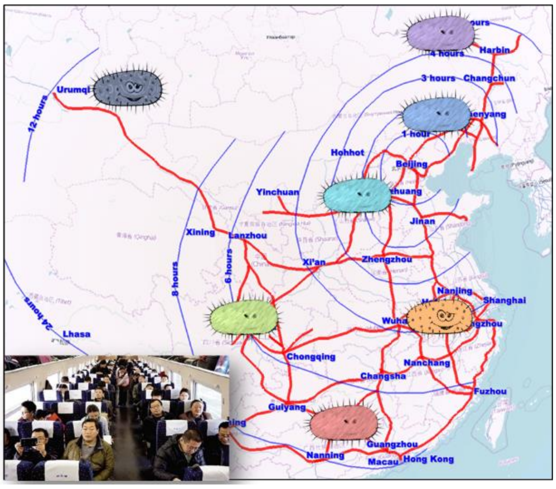


Figure 3.112 The map of spatial distribution of microbial communities along the travel routes

Methodology

Current microbial analysis methods have been widely applied to relatively high-biomass microbial habitats, such as bioreactors. Applications in outdoor and indoor air research, however, is a challenge, partly owing to the ultra-low microbial biomass available for DNA from airborne air samples. A study has been proposed, which will employ a newly developed third-generation high throughout DNA sequencing system. This technique allows the generation of relatively comprehensive microbial community data even from low DNA content air samples. From the scientific perspective, such as an anticipated cutting-edge technique to yield high-quality metagenomic data to identify the microbes, genes, and enzymes from air and human waste samples of serviced high-speed rail carriages. The advanced third-generation sequencing platform, Pacific BioSciences (PacBio) Sequel System, will be used individually or in combination with the Illumina MiSeq platform to enable powerful metagenomic analysis. The system is expected to have a seven-fold higher throughput than its predecessor, the RSII System and is capable of generating data for full-length transcriptomes and targeted transcripts up to a 10-kb read length. By cross-referencing 16S ribosomal RNA gene metagenomic data from both the PacBio and Illumina platforms, the identification quality of the microbes of interest and their bacterial taxonomy classification will be amplified to better quantify microbes. The latter is difficult with the previous techniques.

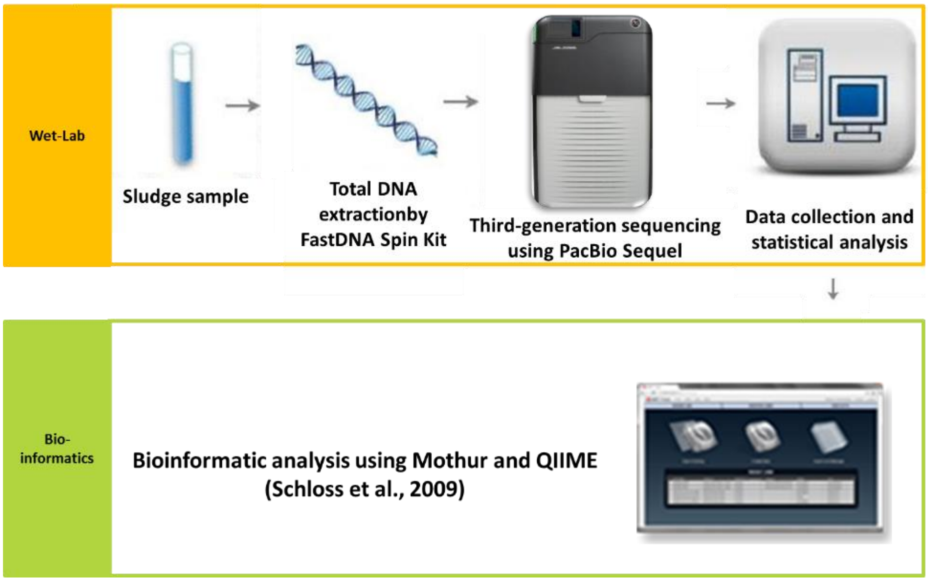


Figure 3.113 The advanced third-generation sequencing platform

3.4.4 The Energy Efficiency and Global Mobile Sensing Environment Enabled by High-Speed Rail

<u>Motivation</u>

high-speed rail is a safe, efficient and environment-friendly transportation mode. This project aims to make use of HSR as a mobile platform to carry out an air quality study in China. An air pollutant sampling and analysis system based on HSR has been designed and its feasibility tested under high wind speed. A sensor system for air quality monitoring has been developed. The air pollutant sampling and analysis system and the sensor system were both confirmed to be stable, robust and reliable. Field deployment of the sensor system in Africa provided reasonable magnitudes and diurnal patterns of air pollutants. This research lays a solid foundation for future air quality studies based on the HSR mobile platform and will help to extend HSR applications to more fields, particularly in the improvement of humans' lives, one example being the construction of the smart city.

There are currently many studies regarding the examination of regional air quality. However, few focuses on national inter-city transport air pollution. The wide coverage of the routes of HSR provides an excellent opportunity for inter-comparisons of air quality among cities and also enables the investigation of the air quality of transportation systems and the ease of otherwise of how they can contribute to the spread of pollution within immediate exterior areas.

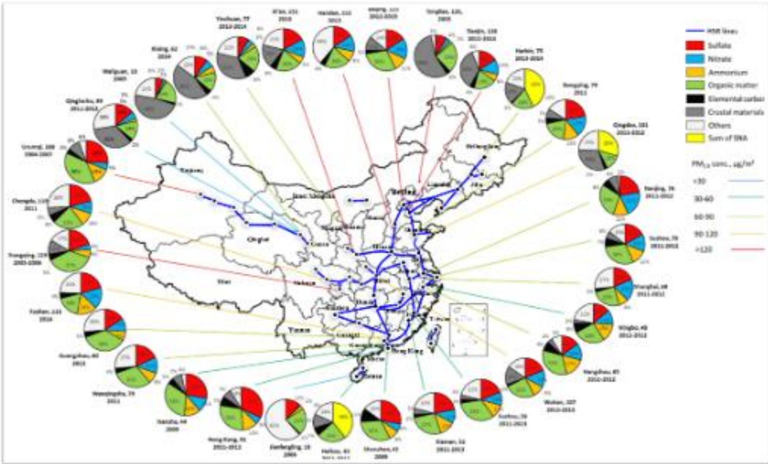


Figure 3.114 A map of HSR lines and chemical composition of PM2.5 in major cities of China

<u>Methodology</u>

Sampling & Analysis System of Air Pollutants

To test the feasibility of applying these HSR instruments, an array of comprehensive wind tunnel experiments was designed and conducted in the laboratory. The aerodynamics around HSR in driving mode were simulated by the FLOTEK 1440 wind tunnel (as shown in the figure). The analysis system was assembled by a set of portable devices. The sampling inlet followed the same direction as the forward direction of the train. For detection cigarettes and paints were used as the sources of air pollutants.

Figure 3.115 FLOTEK 1440 Wind tunnel

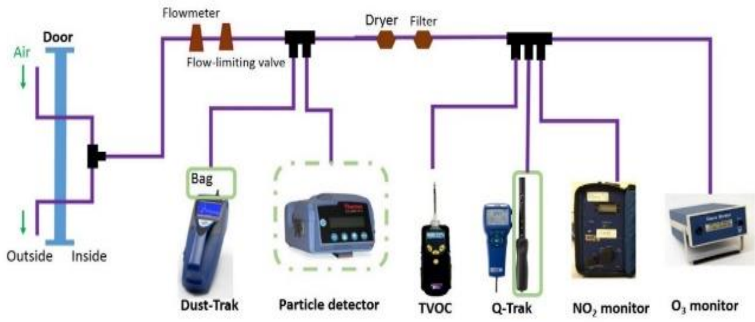


Figure 3.116 Schematic diagram of devices connection

- The ambient air samples were successfully collected and analyzed by our system;
- For all the air pollutants, the concentrations measured under different status were comparable;
- Overall, the sampling & analysis system was reliable, stable and robust for operation.

Table 3.3 Mean concentrations of air pollutants measured under different wind speeds

	Status	Test 1	Test 2	Test 3
$PM_{2.5}$ ($\mu g/m^3$)	Indoor	30.66±0.36	31.86±0.16	31.68±0.29
	180km/h	31.08±0.17	31.84±0.21	31.40±0.17
	240km/h	31.19±0.13	32.14±0.26	31.83±0.15
TVOC (ppb)	Indoor	148.54±3.61	199.47±8.22	224.08±9.70
	180km/h	154.02±7.35	209.17±11.44	228.30±7.29
	240km/h	163.07±14.09	191.36±12.00	242.06±11.34
NO_2 (ppb)	Indoor	51.68±2.21	41.04±2.69	43.59±1.33
	180km/h	51.70±3.66	38.45±0.2	42.90±0.46
	240km/h	49.85±5.94	38.63±0.27	43.06±0.26
O_3 (ppb)	Indoor	6.30±1.11	7.09±0.88	7.91±1.19
	180km/h	5.02±0.90	7.01±1.03	6.20±1.25
	240km/h	6.27±1.05	7.68±1.63	7.46±1.99

Sensor Systems

A quick detection system was designed for air quality monitoring using eight chemical sensors (Alpha Instruments, Inc.). All sensors were fixed and connected to the tubes. The sensors were then read, and the voltage signals recorded by a microcontroller board. Data were continuously transmitted through the USB connection port and converted to the concentrations of air pollutants according to the air pollutant and sensor specific linear relationships between the voltage and concentration.

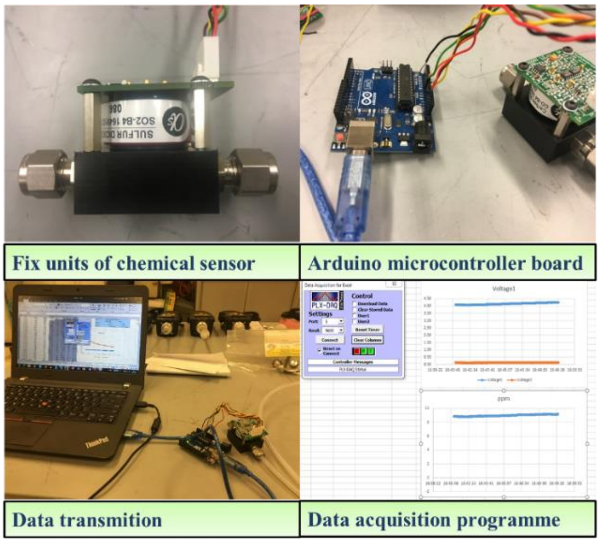


Figure 3.117 Development of chemical sensor system

To ensure stability and reliability, sensors were tested and calibrated by standard gases in the laboratory. For further tests, a set of chemical sensors were deployed in Africa (Lagos, Nigeria) to monitor the air quality.

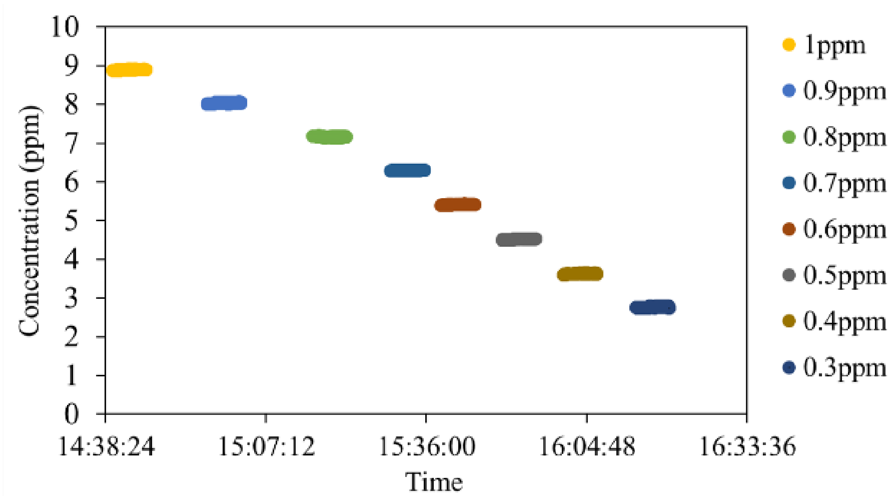


Figure 3.118 Stability of sensor under different concentrations of standard gas

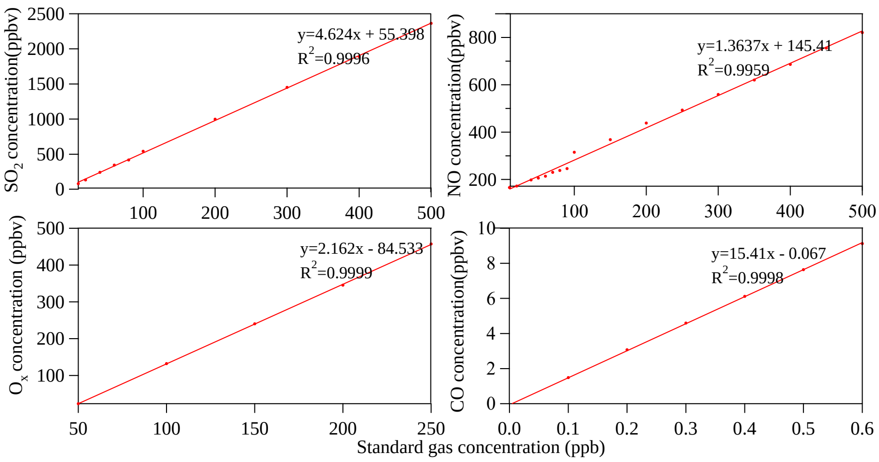


Figure 3.119 Calibration curves of SO_2, NO, O_x and CO sensor

- The precision of the sensor detection system was less than 10% (Figure 3.118);
- Good linear correlations were obtained between electrical signals and concentrations (R^2>0.99 for all the sensors) (Figure 3.119);
- The mixing ratios and the diurnal patterns of the air pollutants detected by the sensors were reasonable (3.120).

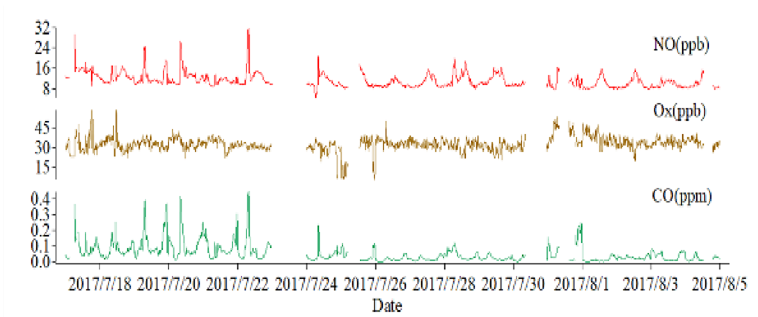


Figure 3.120 Day-to-day variations of NO, O_x and CO concentrations measured by chemical sensors in Africa between 17 July and 4 August, 2017

Conclusions

An air pollutant sampling & analysis system and a sensor system based on the mobile platform of the high speed has been designed in this project. Their feasibility and stability are tested in the laboratory and by field measurements. The results reveal that both are stable, robust, and sufficiently reliable to be applied on high-speed rail.

4. Research-Enhanced Learning

Since its establishment in October 2015, in addition to innovatory and technical development activities, CNERC-Rail, by making use of its expertise and experimental facilities, has provided continuous training opportunities to our students to support their learning activities in the following ways.

4.1 Providing Summer Training with Funding Support for Two Undergraduates in 2018

During the training, students took part in Railway Tunnel Deformation Monitoring experiments in the Center's laboratory, learnt the principle of FBG sensing technology, and helped to set up a simulation test and to monitor the data acquisition process. CNERC-Rail also offered two summer training positions to undergraduate students in 2018.

Figure 4.1 Experimental study carried out by summer training students

4.2 Supporting Students' Final Year Project

Students used and analyzed the data collected during the HSR projects in their final year projects. In addition, CNERC-Rail has provided testbeds for the following four final year projects in 2018: (i) Real-time rail condition monitoring enabled by smart sensing technology; (ii) Condition assessment of rail structure using online monitoring data; (iii) L1-norm sparse learning for structural damage detection; and

(iv) Local stress analysis of the canton tower at the structure-mast connection zone using monitoring data.

4.3 Providing Part-time Student Helper Position

Two undergraduate students started their work in CNERC-Rail in 2018. They learnt multiple signal processing and data regression approaches, including blind source separation (BSS) and dynamic Bayesian learning. The experience greatly helps them, regarding expending study modules and carrying out final year projects. Moreover, the practice of software related to CNERC-Rail has equipped them with computer knowledge for data processing and analysis.

4.4 Incorporating Research Deliverables as Case Studies to Enhance the Teaching and Learning Environment

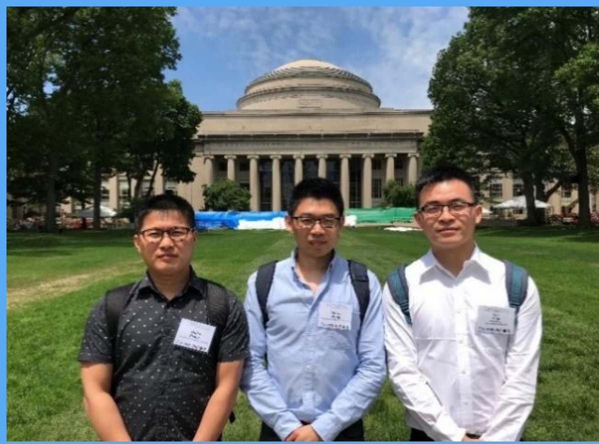
Some research deliverables arising from CNERC-Rail have been incorporated into the lecture and tutorial materials to enhance teaching and learning environment of the following subjects: (i) MSc subject - Seismic Design of Building Structures; and (ii) BEng subject - Advanced Structural Analysis.

5. Our Events

International Conferences

Engineering Mechanics Institute (EMI) Conference in Boston, USA

From 29 May to 1 June 2018, Dr. You-Wu Wang, Mr. Qiu-Hu Zhang and Mr. Si-Qi Ding from CNERC-Rail attended the Engineering Mechanics Institute (EMI) Conference held at Boston, USA. The EMI conference is hosted annually by ASCE, with the aim of disseminating the most recent progress in Engineering Mechanics as a core discipline of science-enabled civil engineering, in the broadest sense. The EMI 2018 conference was organized by the Massachusetts Institute of Technology in Cambridge. Up to 900 scholars from around the world attended. Dr. You-Wu Wang delivered a presentation on "Automated Damage Detection for High-Speed Train Wheels Based on the Bayesian Dynamic Linear Model". Mr. Qiu-Hu Zhang delivered a presentation on "Bayesian Spectrum Approach for Wheel Flat Identification", and Mr. Si-Qi Ding delivered a presentation on "Self-Sensing Cementitious Composites Incorporated with Hierarchical Composite of Carbon Nanotube Grown on Carbon Fiber".



The 6th International Symposium on Reliability Engineering and Risk Management in Singapore

During 31 May and 1 June 2018, the 6th International Symposium on Reliability Engineering and Risk Management was held in Singapore. Prof. Yi-Qing Ni gave a keynote speech entitled “Compressive Sensing and Sparse Bayesian Learning in Structural Health Monitoring: Applications to Large-Scale Bridges and High-Speed Rail” at the conference.

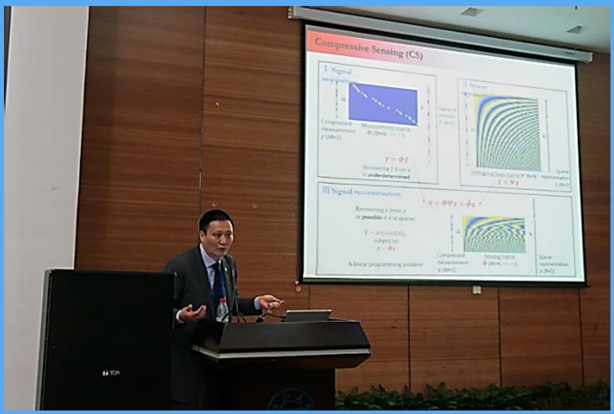
The purpose of this symposium is to stimulate discussion on how resilient and cost-effective solutions could be developed to reduce the vulnerabilities by developing complex systems and networks, and specifically, pertinent infrastructure designed to be resilient at a minimum level of risk proneness. The goal of the symposium is to enhance resilience capability of structures which are either prone to or has suffered from physical disturbance in the past.

The 1st ZHITU Symposium on Advances in Civil Engineering in Hangzhou, China

Prof. Yi-Qing Ni, Director of CNERC-Rail was invited to participate in the 1st ZHITU Symposium on Advances in Civil Engineering held on 12-14 July 2018 in Hangzhou, China. The symposium was jointly hosted by 5 universities: Zhejiang University, The Hong Kong Polytechnic University, University of Illinois Urbana Champaign, USA, University of Tokyo, Japan, and Ulsan National Institute of Science & Technology, Korea. The purpose of the symposium is to promote international collaboration among the 5 universities regarding, in particular, education, research, and challenging exchange programs of civil engineering.

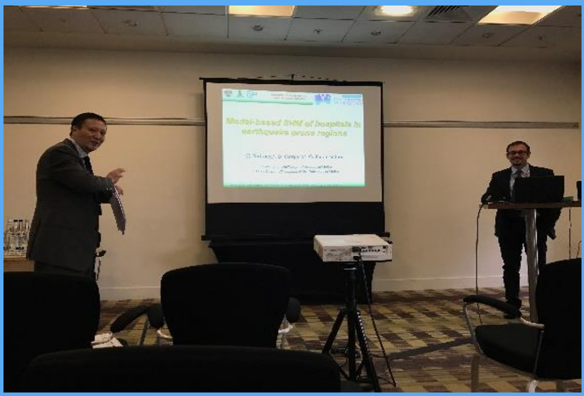
Prof. Ni delivered a keynote speech entitled "Bayesian Machine Learning in Structured Health Monitoring" at the symposium. During his presentation, he stated and strongly emphasized the role of Machine Learning in structural health monitoring. He then, as a guest, attended the inauguration of the International Research Institute of Smart Structure Systems and Informatics.

Mr. Lin-Hao Zhang, whose research paper entitled "Stability and Dynamic Analysis of Standing Vertical Plates under Thermal Effect" won the "ZHITU Student Paper Award" in the symposium. Mr. Zhang is supervised by CNER-Rail member Dr. Siu-Kai Lai.



The 9th European Workshop on Structural Health Monitoring (EWSHM) in Manchester, UK

During 10 to 13 July 2018, Director of CNERC-Rail, Prof. Yi-Qing Ni, and CNERC-Rail member Mr. Si-Xin Chen attended the 9th European Workshop on Structural Health Monitoring (EWSHM), held at Manchester, UK. EWSHM started in 2002, and it is one of the most important SHM international conferences in its field.



Prof. Ni was invited to chair the session “SHM for civil engineering 4”. This session aims to provide researchers with opportunities to share their recent civil engineering SHM studies. At another session “SHM for railroads”, Mr. Chen presented two papers on “Compressive Sensing for Vibration Signals in High-Speed Rail Monitoring” and “Compressive Sensing for High-Speed Rail Condition Monitoring”.

The 7th World Conference on Structural Control and Monitoring in Qingdao, China

During 22 to 25 July 2018, Prof. Yi-Qing Ni and CNERC-Rail members were invited to attend the 7th World Conference on Structural Control and Monitoring held in Qingdao, China. Prof. Ni was invited to chair a keynote speech session during the conference.

CNERC-Rail organized the special session "Structural Monitoring and Control of High-speed Railway" at the conference. Prof. Ni hosted the special session and delivered an invited speech on "Experiential Study of the Effect of MR-Damper on High-Speed Train Bogie". Seven scholars from University of Southern California, University of Central Florida, The Hong Kong Polytechnic University, University of Tokyo, The University of New Mexico, China University of Petroleum and Shijiazhuang Tiedao University delivered presentations in the session. The topics include wheel defect monitoring, assessment of ride comfort for operating trains, rail stress monitoring using non-contact methods and investigations of wireless sensors applied for railway bridges. CNERC-Rail members Dr. Xiao-Zhou Liu and Mr. Chi Xu also delivered speeches on "Online Wheel Tread Defect Detection for High-Speed Trains Using Bayesian Approach" and "A Bayesian Blind Source Separation Method for Noise Observations by Embedding Gaussian Process Prior".

The 9th Cross-strait Summer School on Monitoring and Control in Civil Engineering in Fuzhou, China

During 19 to 22 August 2018, Prof. Yi-Qing Ni and CNERC-Rail member Mr. Si-Qi Ding were invited to attend the 9th Cross-strait Summer School on Monitoring and Control in Civil Engineering (MCCE) held in Fuzhou, China. The MCCE conference was created and implemented by Zhejiang University, Tongji University, The Hong Kong Polytechnic University, Taiwan University, Taiwan Central University, Research Center for Earthquake Engineering in Taiwan, and University of Macau. Prof. Ni delivered a keynote speech on "Bayesian Source Separation in Structural Health Monitoring" and chaired a keynote presentation session.

Mr. Si-Qi Ding delivered a presentation on "Properties and Application of Novel Pressure-Sensitive Sensors Developed with Field Assisted Quantum Tunneling Composites".


特邀报告证书

第九届海峡两岸高校师生土木工程监测与控制研讨会

Cross-strait Work Shop on Monitor and Control in Civil Engineering

(2018年8月19日-22日，福州)

特邀报告专家

倪一清　教授

中国振动工程学会结构抗振控制与健康监测专业委员会

二〇一八年八月

High-end Academic Forum on Smart Transportation and Safety Maintenance in Shenzhen, China

On 4 September 2018, Prof. Yi-Qing Ni and CNERC-Rail team members were invited to attend the High-end Academic Forum on Smart Transportation and Safety Maintenance held at Shenzhen, China. This forum was organized by Institute of Urban Smart Transportation & Safety Maintenance, Shenzhen University. A number of renowned scholars in related fields from mainland China attended this event. Others from Hong Kong, U.S., and Japan also joined the forum. Prof. Ni was invited to deliver an invited speech on "Online Real-time Monitoring for Metro and High-speed Rail Systems".

Prof. Ni was appointed as a Guest Professor at the Institute of Urban Smart Transportation & Safety Maintenance, Shenzhen University, for a period of three years. After the forum, Prof. Ni visited Shenzhen Key Laboratory of Spatial Smart Sensing and Services in the campus of Shenzhen University. A consensus was reached to establish the Guangdong-Hong Kong-Macau Greater Bay Area Modern Rail Transit Collaborative Innovation Center.


聘书

兹聘请 倪一清 教授为深圳大学城市智慧交通与安全运维研究院客座教授，聘期三年。

城市智慧交通与安全运维研究院
2018年9月

深圳大学

The 4th International Conference on Railway Technology in Barcelona, Spain

During 3 to 7 September 2018, Dr. Xiao Wang, Research Associate of CNERC-Rail, attended the 4th International Conference on Railway Technology held in Barcelona, Spain. The conference involved more than 500 international delegates from railway bureaus, industrial companies and research institutes. During the session "R0701-Condition Monitoring and Planning", Dr. Xiao Wang gave a presentation on "On-board Condition Monitoring of High-speed Trains during Route Operations". In addition, Dr. Wang was invited to co-chair two sessions with Prof. Hitoshi Tsunashima and Prof. Yu-Jin Lim for "R0703-Condition Monitoring and Planning" and "R0704-Condition Monitoring and Planning".

The 2nd International Workshop on Structural Health Monitoring for Railway System (IWSHM-RS) in Qingdao, China

During 17 to 19 October 2018, CNERC-Rail team members Dr. Lu Zhou, Dr. Xiao-Zhou Liu and Mr. Yu-Hung Pai, together with three PhD students, Mr. Qiu-Hu Zhang, Mr. Chi Xu and Mr. Si-Xin Chen attended the 2nd International Workshop on Structural Health Monitoring for Railway System (IWSHM-RS) held in Qingdao, China. This workshop aims to introduce the most advanced structural health monitoring technologies to enhance safety and reliability in railway transportation. The theme of the workshop is "Real-Time Safety Assurance and Life-Time Operation Efficiency". Over 125 papers were submitted to the conference and were reviewed by the Honorable Paper Committee. Two CNERC-Rail members Dr. Xiao-Zhou Liu and Mr. Yu-Hung Pai won the Outstanding Paper Award and Honorable Paper Award, respectively.

CNERC-Rail jointly hosted a special session with the China Academy of Railway Sciences (CARS) and Southwest Jiaotong University (SWJTU). Dr. Zhou chaired the special session and CNERC-Rail team members gave six presentations and displayed two informative posters. In the special session, team members had academic exchanges with CARS and SWJTU on such as condition monitoring for railway vehicles and tracks and machine learning techniques for fault detection. After the workshop, CNERC-Rail team members paid a visit to Qingdao Institute of Southwest Jiaotong University and had a meeting with Prof. Jian-Hui Lin's team to discuss future collaborations regarding smart railway systems.

The 2nd Guangdong-Hong Kong-Macau Greater Bay Area Rail Transit Forum in Shenzhen, China

On 31 October 2018, the 2nd Guangdong-Hong Kong-Macau Greater Bay Area Rail Transit Forum was held in Shenzhen by the National Rail Transit Electrification and Automation Engineering Technology Research Center of Southwest Jiaotong University. This forum was jointly organized by PolyU and CNERC-Rail.

Prof. Yi-Qing Ni was invited to deliver a keynote speech on "Online and Real-time Monitoring of Rail Systems: Sensing Network and Algorithm Implementation".

After the forum, a technical meeting of National Rail Transit Electrification and Automation Engineering Technology Research Center was held. CNERC-Rail members Dr. Zhen Leng, Dr. You Dong and Ms. Autumn Lin also attended the forum.

Forum on "Era of Intelligent and Robust Railway" in Tainan, China

On 16 November 2018, Forum on "Era of Intelligent and Robust Railway" was jointly organized by Taiwan Cheng Kung University and CNERC-Rail. Led by Prof. Yi-Qing Ni, a delegation from CNERC-Rail went to Tainan to attend the forum. Prof. Ni and Dr. Lu Zhou delivered invited speeches on "Data Driven Fault Diagnosis and Prognosis of High-Speed Rail Systems" and "Frontiers of Advanced Sensing Technologies Applications in High-Speed Rail Monitoring" respectively. This forum attracted around 300 participants. Ten speakers from government institutions, academic centers and universities gave presentations.

Opening Ceremony of High-Speed Railway Committee of China Railway Society (CRS) and the 2nd Forum on Smart Railway Technology in Beijing, China

From 17 to 18 November 2018, the High-Speed Railway Committee of China Railway Society (CRS) organized the 2nd Forum on Smart Railway Technology in Beijing, China. This event was jointly organized by CRS, State Key Laboratory of Rail Traffic Control and Safety of Beijing Jiaotong University, Ministry of Education Key Laboratory of High-Speed Railway Engineering of Southwest Jiaotong University (SWJTU), CNERC-Rail, and the Infrastructure Inspection Research Institute of China Academy of Railway Sciences and SWJTU Railway Development Co., Ltd.

Led by Prof. Ping-Kong Alexander Wai, Vice President (Research Development), a delegation from PolyU including Prof. Yi-Qing Ni and Prof. Kang-Kuen Lee attended the forum.

Prof. Wai gave a speech to wish the conference a complete success and briefly introduced the meaningful impact of the commission of Hong Kong section of high-speed rail to Hong Kong's development. He also invited the conference attendees to join the 3rd Forum on Smart Railway Technology to be held in Hong Kong.

Prof. Yi-Qing Ni was invited to deliver a keynote speech on “Probabilistic Machine Learning for Interpreting Real-Time Monitoring Data of Railways”.

In the closing ceremony, Dr. Guo-Tang Zhao, Vice Chairman of CRS, appreciated the experts and academics for attending this meeting. He stressed that the committee would follow the “going out” strategy to carry out related works, focusing on the smart high-speed rail, future high-speed rail technology, high-speed rail safety operation technology, high-speed rail management technology, high-speed rail detection, and inspection capacity.

The 1st “Belt and Road” Symposium on Innovative Technologies for Infrastructure in Shanghai, China

On 9 December 2018, Prof. Yi-Qing Ni, Prof. Xiao-Li Ding and Dr. Su-Mei Wang were invited to attend the 1st “Belt and Road” Symposium on Innovative Technologies for Infrastructure held in Shanghai, China. On the symposium, Prof. Ni delivered an invited speech on “Recent Technologies and Methods for Structural Health Monitoring Application”. He introduced the recent techniques and methods for structural health monitoring (SHM) application, including Bayesian framework, compressive sensing method, and deep learning method for SHM and several novel sensors for chemical monitoring, and presented the application of the recent techniques and methods on long-span bridges and high-rise buildings. CNERC-Rail key member Prof. Ding also gave an invited speech.

Visitors to CNERC-Rail

On 26 January 2018, Mr. Hong-Cou Gu, Chairman of Qingtie Railway Technology Corporation Ltd. paid a visit to CNERC-Rail. CNERC-Rail also invited Ir. Wilson Ho, Director of Wilson Acoustics Ltd., the largest acoustic consulting firm in Hong Kong and Dr. Robert Tam, Associate Director of Industrial Centre in PolyU to participate in the meeting. Both parties discussed the application of new technology in railway industry including the use of 3D printing technology to develop innovative Structured Rail Dampers (SRD) for noise and vibration suppression.

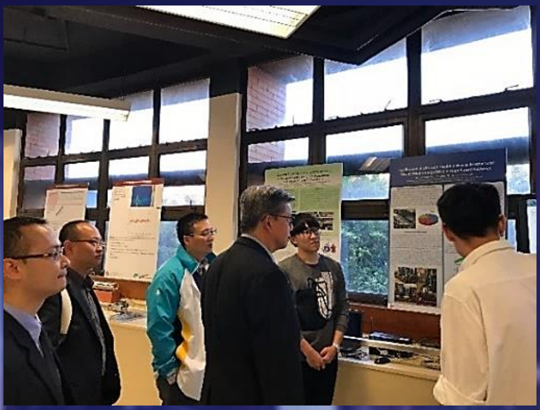
Further collaboration between PolyU and Qingtie Railway Technology Corporation Ltd. was explored. A joint research project entitled "Surface Hardening for Railway Turnout Frog made by Manganese Steels" was launched. This project aims to develop new flexible-controlled high energy peening technology and stimulate innovative ideas to achieve safety and enhance the reliability of HSR systems.

On 28 February 2018, Prof. David Nethercot, Emeritus Professor of Imperial College London and Fellow of Royal Academy of Engineering, and Prof. Yeong-Bin Yang, Honorary Dean of Civil Engineering in Chongqing University, and Academician of Chinese Academy of Engineering paid a visit to CNERC-Rail. Prof. Yi-Qing Ni and Center members Dr. Lu Zhou, Dr. Xiao-Zhou Liu and Dr. Xiao Wang received the guests. Dr. Lu Zhou gave an introduction of CNERC-Rail including R&D activities and projects conducted by CNERC-Rail.

During the meeting, Prof. Nethercot and Prof. Yang had a discussion with CNERC-Rail members and provided insightful suggestions on the future research of CNERC-Rail.

On 20 March 2018, Mr. Bor-Kiat Ng, Chief Technology Officer (CTO) and Mr. Choon-Siong Kho of SMRT Corporation Ltd. paid a visit to CNERC-Rail. Prof. Yi-Qing Ni and Center members Dr. Lu Zhou, Ms. Autumn Lin had a meeting with the visitors. Dr. Lu Zhou gave a presentation and introduced in detail the projects of CNERC-Rail.

After the meeting, CNERC-Rail members accompanied the visitors to visit the Center's laboratory. The research project of high-speed rail tunnel deformation monitoring system and other technologies applied in high-speed rail and metro were introduced during the visit.



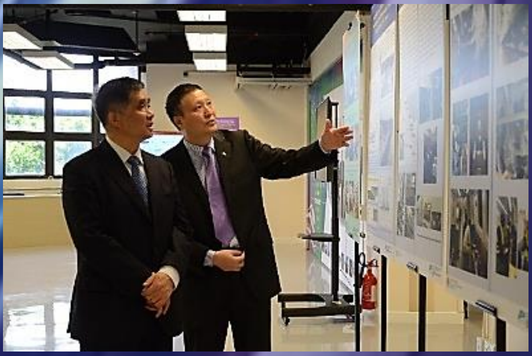
On 14 May 2018, Mr. Yuen-Ming Liong, Head of Future Systems and Mr. Choon-Siong Kho of SMRT Corporation Ltd. paid a visit to CNERC-Rail. Prof. Yi-Qing Ni and Center members Dr. Lu Zhou, Dr. Qi-Ang Wang, Ms. Autumn Lin, and Mr. Jason Leung had a meeting with the visitors. Dr. Lu Zhou gave a presentation about CNERC-Rail, and later, after the meeting, the visitors were led to visit the Center's laboratory. Dr. Qi-Ang Wang explained the research projects of the Center to the visitors, including real-time condition assessment of railway tunnel deformation using an FBG-based monitoring system.

On 8 June 2018, accompanied by Prof. Ping-Kong Alexander Wai, Vice President (Research and Development), Dr. Peter Ewen, Engineering Director and Mr. Peter Hui, Engineering Manager–Rolling Stock of MTR Corporation paid a visit to PolyU and CNERC-Rail. CNERC-Rail researchers introduced the Center's research projects to the visitors, including the high-speed rail tunnel deformation monitoring system, condition monitoring and load transmission evaluation of Beijing-Shenyang HSR track slabs using embedded FBG sensor arrays, and the performance monitoring of metro trains on Olympic Lines in Brazil.

Apart from the visit to CNERC-Rail, the visitors also visited PolyU-KCRC Smart Railway Research Laboratory, Specialty Optical Fiber Fabrication Laboratory, Digital Manufacturing Facility, and Aviation Service Research Center.

On 11 June 2018, led by Prof. Bin Ning, President of Beijing Jiaotong University and Academician of Chinese Academy of Engineering, a delegation visited PolyU and CNERC-Rail. The President of PolyU, Prof. Timothy W. Tong and senior management received the delegation. During the meeting, both parties were interested in exploring the possibility of more university-to-university collaborations, especially in the field of railway engineering.

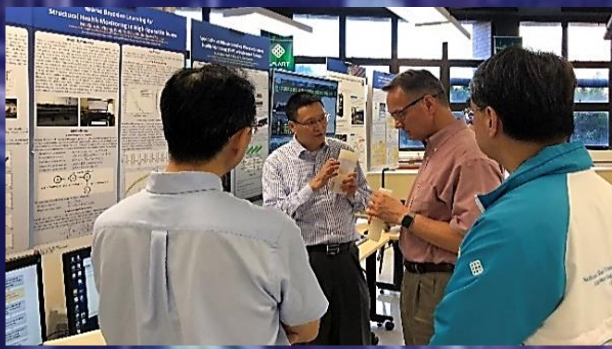
After the meeting, Prof. Ning paid a visit to the Center's laboratory. Prof. Yi-Qing Ni introduced the recent research projects to him. CNERC-Rail members also introduced the Radio Frequency Identification (RFID) technology, devised to measure the change of strain and temperature in HSR. Prof. Tam and Dr. Shun-Yee Liu introduced their projects.



On 10 July 2018, led by Mr. Han-Hua Chen, Director of Innovation and Technology, the Bureau of Zhaoqing Government, a delegation from Zhaoqing Government paid a visit to PolyU. Prof. Guo-Hua Chen, Associate Vice President (Research Support) of PolyU greeted the visitors. Prof. Yi-Qing Ni, Director of CNERC-Rail was invited to join the meeting and greet the visitors. Prof. Ni gave a presentation about CNERC-Rail and introduced the Center's latest research projects. Dr. Victor Zhao, Assistant Director of Innovation and Technology Development Office (ITDO) of PolyU and Ms. Maggie Chen, Director of PolyU Shenzhen Base attended the meeting. Both parties agreed to look for more collaborations by capitalizing on the opportunities arising from the Guangdong-Hong Kong-Macau Greater Bay Area development.

On 27 July 2018, a delegation organized by the Hong Kong Institute of Acoustics visited CNERC-Rail. The participants included MTR Corporation, Wilson Acoustics Ltd., Environmental Protection Department of HK Government and Scholars from various universities in Mainland China and Taiwan. Ms. Autumn Lin, Assistant Officer of CNERC-Rail introduced CNERC-Rail to the visitors. Later, Dr. Siu-Kai Lai, Assistant Professor, a member of CNERC-Rail introduced several impact research projects to the visitors. The delegation then paid a visit to the Center's laboratory, 3D Printing Laboratory, and Aviation Service Research Centre.

On 8 August 2018, Prof Billie F. Spencer from University of Illinois at Urbana-Champaign, USA visited CNERC-Rail. Dr. Lu Zhou introduced the Center's latest research development to Prof. Spencer. Later, Prof Spencer visited the Center's laboratory and 3D Printing Laboratory.



On 28 August 2018, led by Mr. Kelvin Fong, Engineering and Technical Director, a delegation from Thales Transport & Security (Hong Kong) Ltd. visited CNERC-Rail. Prof. Yi-Qing Ni and Center's research team introduced the latest achievements of CNERC-Rail to the visitors.

After the meeting, Thales visited the Center's laboratory and further discussions were conducted during the visit.

On 27 September 2018, led by Prof. Shou-En Fang, a delegation from Tongji University visited PolyU and CNERC-Rail. Mr. Hui-bin Pan from the Hong Kong and Macau Affairs Office of the State Council accompanied the visitors to PolyU. The visitors showed great interest in the research projects that CNERC-Rail had completed.

On 3 October 2018, a delegation from Xi'an Jiaotong University visited PolyU and CNERC-Rail. CNERC-Rail team members introduced the latest research technology to the visitors.

On 19 October 2018, Prof. Fabio Casciati and Prof. Lucia Faravelli from University of Pavia, Italy paid a visit to CNERC-Rail. Prof. Yi-Qing Ni and center members Dr. Hua-ping Wan, Dr. You-Wu Wang and Mr. Chao Zhang attended the seminar of "Model Order Reduction and Sensor Features in Active Structural Control" delivered by Prof. Casciati and discussed the application of model order reduction method on bridges and rails with Prof. Casciati. Prof. Ni and CNERC-Rail team members, then showed Prof. Casciati and Prof. Faravelli around the Center's laboratory. Mr. Zhang introduced the recent research achievements of CNERC-Rail related to the fields of health monitoring of rail structures, train vibration control, and railway noise reduction. Prof. Ni introduced the application of the health monitoring system developed by CNERC-Rail to a variety of railway projects.

On 1 November 2018, Dr. Shih-Chi Liu, Visiting Expert from Southeastern University, China visited CNERC-Rail. Dr. Liu gave thoughtful advices and suggestions on the future research of CNERC-Rail.

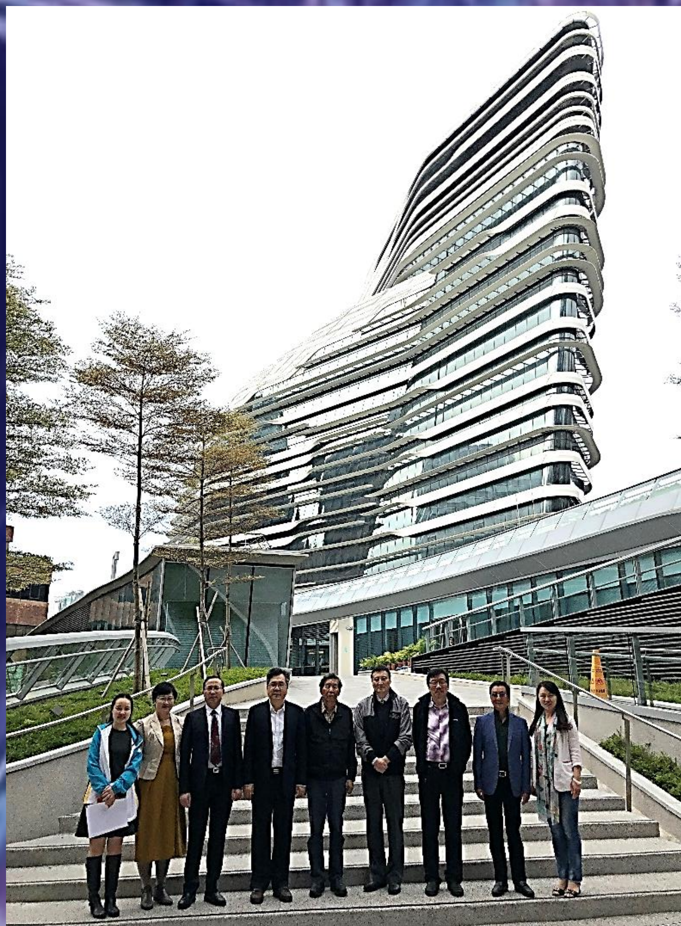
During 19 to 21 December 2018, led by Prof. Chuan He, Vice President of Southwest Jiaotong University, and Prof. Qing-Quan Qian, Academician of Chinese Academy of Engineering, a delegation from National Rail Transit Electrification and Automation Engineering Technology Research Center of Southwest Jiaotong University visited CNERC-Rail to take part in the annual meeting. The delegation consisted of Prof. Chuan He, Prof. Qing-Quan Qian, Prof. Shi-Bin Gao, Prof. Wei-Rong Chen, Prof. Xiao-Qiong He, Prof. Xin Zhang and Mr. Cheng-Hui Liu. On the morning of the 20th, the delegation visited the key laboratories of The Hong Kong Polytechnic University, including the Aviation Engineering Centre, the Joint Laboratory in Precision Engineering for Space Applications, the 3D Printing laboratory, the Center's laboratory, and the Big Data Laboratory.

On 20 December, Prof. Ping-Kong Alexander Wai, Vice President (Research and Development) of The Hong Kong Polytechnic University met the delegation. Examples of relevant advanced research methodologies in the form of project achievements were presented to the guests by PhD students. After the meeting, Prof. He, on behalf of Southwest Jiaotong University, presented a high-speed train model to The Hong Kong Polytechnic University with the sincere hope that both universities could cooperate further on the development of China's high-speed railways and hence better serve the safety of high-speed rail.

On 21 December, Prof. Yi-Qing Ni, Director of CNERC-Rail gave a presentation to the delegation. Prof. Ni introduced the Center's research work, collaborative activities, academic exchanges which had been conducted during the past year. Both parties discussed the methods for monitoring data processing and real-time monitoring on the pantograph of high-speed railways. They also confirmed the continuation of future cooperation in research and talent exchange.

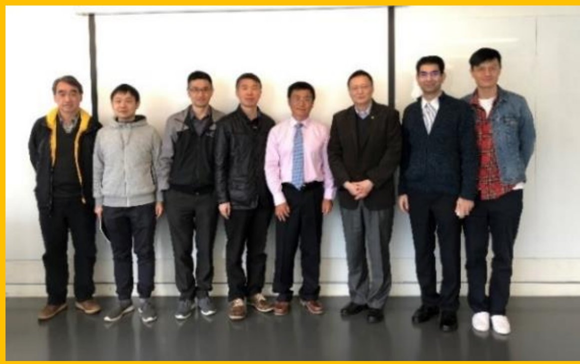
Prof. Qian, in turn, introduced and described the development of high-speed railways and also Maglev systems in China. Prof Qian looked forward to continuing promoting the development of Maglev transport in the Greater Bay Area. Prof. Chen shared and supported several future research directions.

Dr. Song-Ye Zhu, Secretary of CNERC-Rail, Dr. Siu-Kai Lai, and Dr. You Dong attended the meeting. Prof. Kang-Kuen Li, Deputy Director of CNERC-Rail also met the delegation.



Delivered Seminars by Visitors

On 24 January 2018, Professor Jian-Chun Li, Professor of Structural Dynamics and Director of the Centre for Built Infrastructure Research at University of Technology, Sydney, Australia, paid a visit to CNERC-Rail and delivered a seminar on "A Quest Towards a Truly Intelligent Civil Infrastructure". Prof. Li and his team began their research and development on smart materials/structure since 2000. During the seminar, Prof. Li shared with the audience his most recent research on smart structures and discussed the issues related to challenges and future opportunities regarding resilient intelligent structures.



On 2 February 2018, Professor Chen-Ming Kuo, Professor and Head of Department of Civil Engineering at Taiwan Cheng Kung University visited CNERC-Rail and delivered a seminar on "The Effectiveness of Baseplate on Vibration Reduction and the Experiences on Track Measurements". The seminar covered 2 topics including (i) The effectiveness of baseplate on vibration reduction: A study of insertion loss and characteristic frequencies of ballast less track with baseplate based on field measurements and theoretical justification; and (ii) The experiences on track measurements: Introducing experiences on development measurement tools for corruption, side wear, track alignment, and rail temperature.

On 29 March 2018, a seminar entitled "A History of Metal Fatigue and the Development of an Understanding of What it is and Why it still Causes Problems" was delivered by Prof. Roderick A. Smith. Prof. Smith is currently an Emeritus Professor at Imperial College London, and a Fellow of Royal Academy of Engineering. He is also the Chairman of the Future Rail Research Centre at Imperial College London. During the seminar, the issue of metal fatigue was discussed. Metal fatigue is still a major problem and failures occur not only regarding railways, the parent of the problem, but also in a wide range of industries, both in high-tech low-volume products and in low volume, low-tech products. The seminar concluded with a discussion on why this should be and emphasized the empirical aspects.

During 5 to 7 September 2018, Prof. Chia-Chi Cheng from Chaoyang University of Technology, Taiwan visited CNERC-Rail to conduct an experiment on track beds. Stress-wave was used to find the delamination in the three-layer track bed (concrete-CA mortar-concrete). On 6 September, Prof. Cheng delivered a seminar on "Quantitative Assessment of Interfacial Bonding Condition between Steel or Concrete Overlay and Substrates using Stress-Wave Methods".

On 22 October 2018, Prof. Chien-Ming Wang from The University of Queensland, Australia visited CNERC-Rail. Prof. Yi-Qing Ni and center members, as well as many PhD students, attended the seminar entitled: "Floating Solutions for Challenges Faced by Humanity" given by Prof. Wang. The scheme presented by Prof. Wang is novel and fruitfully wise. By fully exploiting the ocean, Prof. Wang provided practical solutions to the world challenges of not enough land usage. After the meeting, Prof. Ni and other participants had in-depth exchanges and discussions with Prof. Wang on his presented report. Prof. Ni then invited Prof. Wang to visit CNERC-Rail, and introduced details of the main research achievements of the center and their applications in the field of structural health monitoring associated with railways and trains over recent years.

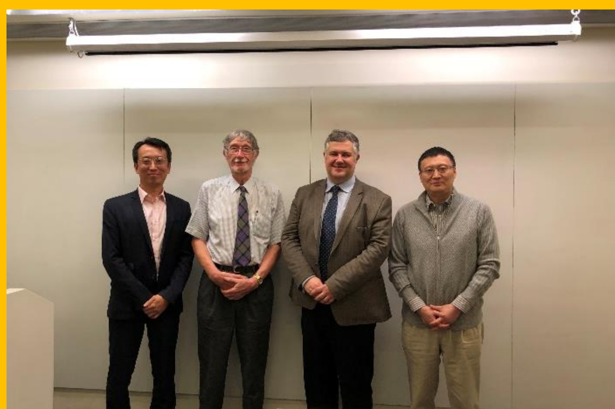
On 12 November 2018, Prof. Sritawat Kitipornchai from The University of Queensland, Australia visited CNERC-Rail. Prof. Yi-Qing Ni and CNERC-Rail members attended the seminar "Tension Diaphragm Bracing Systems" given by Prof. Kitipornchai. Prof. Ni and other participants had in-depth exchanges and discussions with Prof. Kitipornchai after the seminar. Prof. Ni later accompanied Prof. Kitipornchai to visit the Center's laboratory.

On 4 December 2018, Dr. Xu-Dong Qian, Associate Professor at Department of Civil and Environmental Engineering, National University of Singapore visited CNERC-Rail and gave a seminar titled "Fatigue of Welded Tubular Connections – Simplified Weld Protocol and Enhanced Assessment Approach". During the seminar, Dr. Qian first introduced his research works on welded connection problems of tubulars, in which he developed an economical welding profile to replace the traditional one. Assessment of the fatigue life of welded connections was then introduced by Dr. Qian in his seminar, in which the key issue of effective notch stress estimation was discussed.

On 6 December 2018, Dr. Sze-Dai Pang, Associate Professor at Department of Civil and Environmental Engineering, National University of Singapore visited CNERC-Rail and delivered a seminar titled "Graphene Nanoplatelet in Cement Composites for Smarter and More Durable Infrastructures". Dr. Pang and his colleagues have spent years studying on graphene nanoplatelet (GNP), a cheap graphene-based product comprising of multiple graphene layers. In this talk, he reviewed their research activities in the processing of GNP-cement composites and introduced the way they determine the optimum sonication time and superplasticiser dosage. He also discussed the influence of GNP on the sensitivity of this cement composite to change its electrical resistance with changes in compressive and tensile stress.

After the seminar, Dr. Pang visited the Center's laboratory and exchanged views with Center's researchers.

On 7 December 2018, Prof. Clive Roberts, Director of Centre for Railway Research and Education of The University of Birmingham, paid a visit to CNERC-Rail and gave a seminar on "Global Railway Technology Development". Prof. Yi-Qing Ni and CNERC-Rail members attended this seminar. Prof. Roberts first introduced the UK Rail Research and Innovation Network (UKRRIN) and clarified their tasks among science, education and industry. Afterwards, Prof. Roberts highlighted the future requirements for railway, such as higher capacity with lower cost and higher innovation with lower carbon, etc.



On 12 December 2018, Dr. Wei Song from The University of Alabama, USA visited CNERC-Rail and delivered a seminar on “Real-Time Model Updating Techniques for Nonlinear Structural Systems and Damping Devices”. Dr. Song introduced the development of a real-time model updating platform and its application in nonlinear structural system and damping system as well. Hereinafter, Dr. Song introduced a recent work of a joint-input-state estimation technique, which can obtain accurate dynamic models simultaneously and the optimal estimation on the corresponding inputs.

After the seminar, Prof. Yi-Qing Ni and CNERC-Rail members had a technical meeting with Dr. Song on the possible collaboration on the Guangshan HSR project.

On 21 December 2018, Prof. Gen-Da Chen from Missouri University of Science and Technology, USA visited CNERC-Rail and delivered a seminar on “Automation and Informatics in Civil Engineering”. Prof. Chen introduced the INSPIRE (Inspecting and Preserving Infrastructure through Robotic Exploration) which focuses on the future robotic platforms exploration for faster and cheaper inspection and preservation tools to maintain the ground transportation systems. He also delivered the robotic platforms: unmanned aerial vehicle (UAV) and structural crawlers in the structural damage inspection application.

After the seminar, a technical meeting was held to discuss potential application of innovative sensing techniques in railway engineering. Prof. Chen proposed to design robots for condition monitoring of rail tracks.

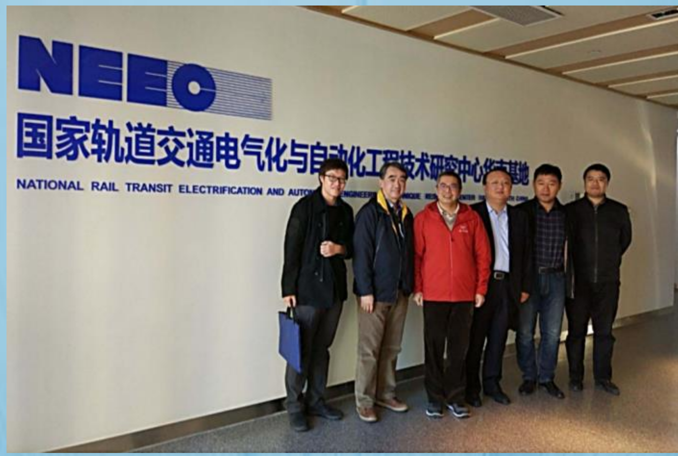
Technical Visits

On 4 January 2018, Director of CNERC-Rail, Prof. Yi-Qing Ni visited China Academy of Railway Sciences and delivered a seminar on "Online Monitoring, Diagnosis, and Prognosis of High-Speed Rail Systems". After the seminar, Professor Ni further discussed the application of the Center's technologies to high-speed railway infrastructure by making use of inspection data.

On 5 January 2018, Prof. Ping-Kong Alexander Wai, Vice President (Research and Development) of PolyU, Prof. Yi-Qing Ni, and Dr. Robert W.M. Tam, Associate Director of PolyU Industrial Centre were invited to visit China Academy of Railway Sciences and China Railway Corporation in Beijing. They had a meeting with researchers from China Academy of Railway Sciences. Both parties agreed that China Academy of Railway Sciences would collaborate with CNERC-Rail to jointly carry out research projects.

Later, Prof. Wai, Vice President (Research Development) of PolyU, Prof. Ni, and Dr. Tam visited China Railway Corporation. Dr. Guo-Tang Zhao, Deputy Chief Engineer, Dr. Peng-Xiang Wang, Dean of Beijing Research Institute of Southwest Jiaotong University and Chairman of China Southwest Railway Development Corporation Ltd. (CSRD) attended the meeting. During the meeting, CNERC-Rail reported the latest research projects and research outcomes. Both parties agreed to jointly conduct projects covering 9 topics.

On 11 January 2018, CNERC-Rail members visited the South China Base of the National Rail Transit Electrification and Automation Engineering Technology Research Center (NEEC) of Southwest Jiaotong University located in Dongguan, China and had a technical meeting with the representatives. Prof. Bin Su, Director of NEEC (South China Base) and Deputy Director of NEEC, Mr. Xuan He, General Manager of Beijing Railway Industrial Group Corporation Ltd., and Mr. Liang Sun, Director of the Research Institute attended the meeting.



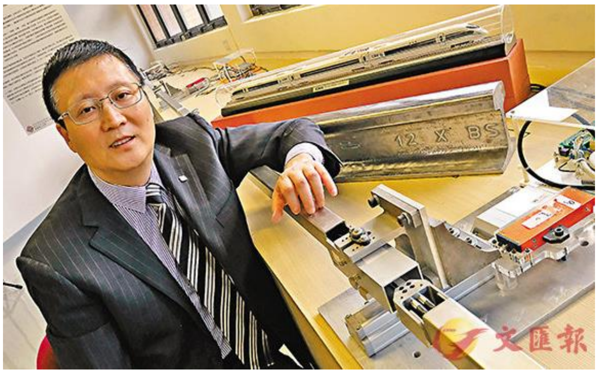
On 9 August 2018, Mr. Guang-Hui Cheng, Deputy Director of PolyU-CSRD Joint Innovation Center for Rail Transit Safety Monitoring Technology (RTSMT), Dr. Xiao-Zhou Liu, Deputy Director of RTSMT, CNERC-Rail members Dr. Qin Hu and Dr. Xiao Wang paid a visit to the headquarters of China Railway Guangzhou Group Ltd. and met Mr. Hao Li, Vice Head of Construction Management Department and Mr. Zhong-Ping Tang, Chief Engineer of Guangzhou-Shanwei High-Speed Railway. During the meeting, CNERC-Rail members presented their latest research projects. China Railway Guangzhou Group Ltd. invited RTSMT to prepare a master plan on an SHM-based and BIM-assisted system for life-cycle management of Guangzhou-Shanwei High-Speed Railway.

Other Activities

On 15 May 2018, CNERC-Rail was invited to join the Forum on Mainland-HK Cooperation in Innovation and Technology hosted by the Hong Kong Special Administrative Region (HKSAR) Government. Ms. Carrie Lam, Chief Executive of the HKSAR, Prof. Tie-Niu Tan, Deputy Director of the Central Government Liaison Office, Mr. Liu-Quan Huang, Deputy Director of the Hong Kong and Macau Affairs Office of the State Council, Prof. Wei Huang, Vice Minister of Science and Technology and over 150 representatives from the HKSAR Government and local academic and research institutions attended the forum. Prof. Yi-Qing Ni, Director of CNERC-Rail and Ms. Autumn Lin, Assistant Officer attended the forum. During the forum, guests discussed the new opportunities brought about by the opening up of science and technology funding by the Ministry of Science and Technology (MOST) and the Ministry of Finance for application by Hong Kong higher education institutions and research institutions. Prof. Timothy W. Tong, President of The Hong Kong Polytechnic University chaired a discussion panel and invited a number of speakers to conduct in-depth discussions on the new policy.

On 13 June 2018, Prof. Yi-Qing Ni, Director of CNERC-Rail was invited to attend a luncheon hosted by the Chief Executive of the HKSAR. The luncheon was held at the Government House. Prof. Tie-Niu Tan, Deputy Director of the Liaison Office of the Central Government in the HKSAR, Mr. Patrick Tak-Kuen Nip, Secretary for Constitutional and Mainland Affairs, Mr. Nicholas Wei-Hsiung Yang, Secretary for Innovation and Technology, and Ms. Annie Choi, Commissioner for Innovation and Technology attended the luncheon.

Media Interviews



Implementing President Jinping Xi's instructions, the Ministry of Science and Technology and the Ministry of Finance of China promulgated in 2018 provisions on opening up science and technology funding of the Central Government for application by higher education institutions and research institutions in Hong Kong, which include the arrangements on cross-boundary remittance of approved research funding to Hong Kong. On 18 May 2018, Prof. Yi-Qing Ni was interviewed by Wen Wei Po, a Hong Kong-based newspaper. Prof. Ni said that CNERC-Rail's research activities can be funded directly from the Ministry of Science and Technology, which would certainly benefit the further cooperation between CNERC-Rail and institutions from Mainland and overseas in the future. From this perspective, the significance of the promulgated policy would be far greater than the funding amount itself. During the interview, Prof. Ni introduced the research project funded by the Hong Kong, Macau and Taiwan Science and Technology Innovation Cooperation Key Project under National Key Research and Development Plan. The Center has started to carry out research of the funded project entitled "Condition monitoring and intelligent data analysis techniques for operation and maintenance strategies of high-speed rail infrastructure system" since June 2018.

On 23 May 2018, Prof. Yi-Qing Ni was interviewed by Television Broadcasts Limited for 'A Closer Look' news program. Prof. Ni said the Center focuses on developing advanced technologies for on-line monitoring and enhancing safety and reliability of China's high-speed rail. Prof. Ni also highlighted the Center's work in promoting the internationalization of China's high-speed rail technologies.

6. Our Profile

The CNERC-Rail research team consists of 13 key members from 5 departments of PolyU. CNERC-Rail also encourages and supports Collaborative Members from different departments to participate in R&D projects funded by CNERC-Rail.

Founding Members

Prof. Yi-Qing Ni

Director

Professor
Department of Civil and Environmental Engineering

Prof. Kang-Kuen Lee

Deputy Director
Director of Research Laboratory for Condition Monitoring and Vibration Control of High-Speed Trains

Professor of Practice (Transportation)
Department of Electrical Engineering

Dr. Song-Ye Zhu

Secretary
Key Member of Research Laboratory for High Speed Rail Traction Power System and Safety Technology, Hong Kong Branch of the National Rail Transit Electrification and Automation Engineering Technology Research Center

Associate Professor
Department of Civil and Environment Engineering

Prof. Ka-Wai Cheng

Director of Research Laboratory for High Speed Rail Traction Power System and Safety Technology, Hong Kong Branch of the National Rail Transit Electrification and Automation Engineering Technology Research Center

Professor
Department of Electrical Engineering

Prof. Siu-Lau Ho

Key Member of Research Laboratory for High Speed Rail Traction Power System and Safety Technology, Hong Kong Branch of the National Rail Transit Electrification and Automation Engineering Technology Research Center

Associate Vice President (Academic Support)

Chair Professor
Department of Electrical Engineering

Prof. Siu-Wing Or

Key Member of Research Laboratory for High Speed Rail Traction Power System and Safety Technology, Hong Kong Branch of the National Rail Transit Electrification and Automation Engineering Technology Research Center

Professor
Department of Electrical Engineering

Prof. Hwa-Yaw Tam

Director of Research Laboratory for Advanced Sensing Techniques for High Speed Rail Monitoring, Hong Kong Branch of the National Rail Transit Electrification and Automation Engineering Technology Research Center

Chair Professor and Head
Department of Electrical Engineering

Prof. Zhong-Qing Su

Key Member of Research Laboratory for Advanced Sensing Techniques for High Speed Rail Monitoring, Hong Kong Branch of the National Rail Transit Electrification and Automation Engineering Technology Research Center

Professor and Associate Head
Department of Mechanical Engineering

Prof. Jian-Nong Cao

Key Member of Research Laboratory for Advanced Sensing Techniques for High Speed Rail Monitoring, Hong Kong Branch of the National Rail Transit Electrification and Automation Engineering Technology Research Center

Chair Professor
Department of Computing

Dr. Dan Wang

Key Member of Research Laboratory for Advanced Sensing Techniques for High Speed Rail Monitoring, Hong Kong Branch of the National Rail Transit Electrification and Automation Engineering Technology Research Center

Associate Professor
Department of Computing

Prof. Xiao-Li Ding

Key Member of Research Laboratory for Condition Monitoring and Vibration Control of High-Speed Trains, Hong Kong Branch of the National Rail Transit Electrification and Automation Engineering Technology Research Center

Chair Professor and Associate Dean (FCE)
Department of Land Surveying and Geo-informatics

Prof. Li Cheng

Key Member of Research Laboratory for Condition Monitoring and Vibration Control of High-Speed Trains, Hong Kong Branch of the National Rail Transit Electrification and Automation Engineering Technology Research Center

Chair Professor
Department of Mechanical Engineering

Dr. Xing-Jian Jing

Key Member of Research Laboratory for Condition Monitoring and Vibration Control of High-Speed Trains, Hong Kong Branch of the National Rail Transit Electrification and Automation Engineering Technology Research Center

Associate Professor
Department of Mechanical Engineering

Members

Prof. Hai Guo

Professor
Department of Civil and Environmental Engineering

Dr. You Dong

Assistant Professor
Department of Civil and Environmental Engineering

Dr. Shu-Chien Hsu

Assistant Professor
Department of Civil and Environmental Engineering

Dr. Siu-Kai Lai

Assistant Professor
Department of Civil and Environmental Engineering

Dr. Po-Heng Lee

Assistant Professor
Department of Civil and Environmental Engineering

Dr. Zhi-Zhao Liu

Associate Professor
Department of Land Surveying and Geo-Informatics

Dr. Zhen Leng

Associate Professor
Department of Civil and Environmental Engineering

Dr. Lu Zhou

Research Fellow
Department of Civil and Environmental Engineering

Dr. Shun-Yee Liu

Senior Scientific Officer
Department of Electrical Engineering

Dr. Yun-Lai Zhou

Research Fellow
Department of Civil and Environmental Engineering

Dr. You-Wu Wang

Postdoctoral Fellow
Department of Civil and Environmental Engineering

Dr. Xiao-Zhou Liu

Postdoctoral Fellow
Department of Civil and Environmental Engineering

Dr. Su-Mei Wang

Postdoctoral Fellow
Department of Civil and Environmental Engineering

Dr. Yan-Jie Zhu

Research Associate
Department of Civil and Environmental Engineering

Visiting Professor

Prof. Wen-Hwa Wu

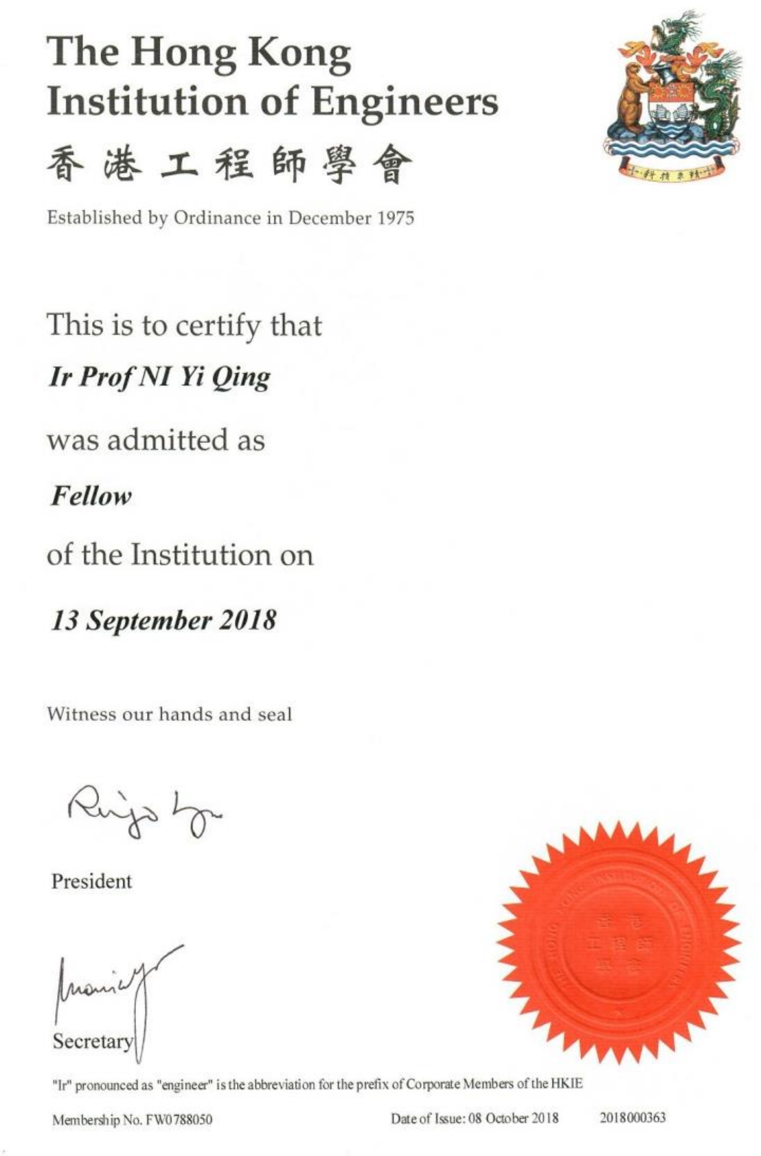
Professor
Department of Civil and Construction Engineering
Yunlin University of Science and Technology

In 2018, CNERC-Rail was granted a maximum budget of HK$ 5 million from the Innovation and Technology Commission (ITC), the Hong Kong Special Administrative Region. Moreover, PolyU has granted a 1:1 matching fund to CNERC-Rail. Hence, the total financial support to CNERC-Rail is HK$ 10 million in 2018.

7. Achievements

7.1 Honors and Awards

Prof. Yi-Qing Ni was admitted as Fellow of The Hong Kong Institution of Engineers.


The Hong Kong Institution of Engineers
香港工程師學會

Established by Ordinance in December 1975

This is to certify that

Ir Prof NI Yi Qing

was admitted as

Fellow

of the Institution on

13 September 2018

Witness our hands and seal

President

Secretary

"Ir" pronounced as "engineer" is the abbreviation for the prefix of Corporate Members of the HKIE

Membership No. FW0788050 Date of Issue: 08 October 2018 2018000363

Prof. Yi-Qing Ni was appointed as a Guest Professor in the Institute of Urban Smart Transportation & Safety Maintenance, Shenzhen University.

Paper “Condition-based maintenance of high-speed railway vehicle wheels through trackside monitoring” (authors: Xiao-Zhou Liu and Yi-Qing Ni) received the Outstanding Paper Award in the 2nd International Workshop on Structural Health Monitoring for Railway System held on 17-19 October 2018 in Qingdao, China.

Paper "Vibration characteristics of direct-fixation track with flexible fasteners" (authors: Chen-Ming Kuo, Cheng-Hao Huang, Chih-Chiang Lin, Yu-Hung Pai, and Yi-Qing Ni) co-authored by a joint team from Taiwan Cheng Kung University and from CNERC-Rail received the Honorable Paper Award in the 2nd International Workshop on Structural Health Monitoring for Railway System held on 17-19 October 2018 in Qingdao, China.

Paper "Stability and dynamic analysis of standing vertical plates under thermal effect" (authors: Siu-Kai Lai and Lin-Hao Zhang) received the Student Paper Award in the 1st ZHITU Symposium on Advances in Civil Engineering on 12-14 July 2018 in Hangzhou, China.

Dr. You Dong received the "Young Award" at the IABMAS 2018 (International Conference on Bridge Maintenance, Safety and Management), Melbourne, Australia, 9-13 July 2018.

Bin Wang, Song-Ye Zhu, You-Lin Xu, Huan-Jun Jiang received the Commendation Merit Award – R&D Award of Structural Excellence Award 2018, The Hong Kong Institution of Engineers – the Structural Division.

Mr. Yuan-Hao Wei received ASCE's Best Master's Thesis Award and was invited to attend the 2018 ASCE Annual Dinner with his supervisor Prof. Yi-Qing Ni.

7.2 Publications and Presentations

63 Papers in total, including 38 journal papers and 25 international conference papers, were published in 2018, in which fund support from CNERC-Rail was acknowledged:

(A) Journal Papers

1. Chen, Z. W., Cai, Q. L., & Zhu, S. (2018), "Damage quantification of beam structures using deflection influence lines", *Structural Control and Health Monitoring*, 25(11), e2242. (SCI)

2. Ding, S., Ruan, Y., Yu, X., Han, B., & Ni, Y. Q. (2019), "Self-monitoring of smart concrete column incorporating CNT/NCB composite fillers modified cementitious sensors", *Construction and Building Materials*, 201, 127-137. (SCI)

3. Dong, Y. (2018), "Performance assessment and design of ultra-high performance concrete (UHPC) structures incorporating life-cycle cost and environmental impacts", *Construction and Building Materials*, 167, 414-425. (SCI)

4. Geng, Q., Zhu, S., & Chong, K. P. (2018), "Issues in design of one-dimensional metamaterials for seismic protection", *Soil Dynamics and Earthquake Engineering*, 107(1), 264-278. (SCI)

5. He, W. Y., Wang, Y., & Zhu, S. (2018), "Adaptive reconstruction of a dynamic force using multiscale wavelet shape functions", *Shock and Vibration*, 2018. (SCI)

6. He, W. Y., Zhu, S., & Chen, Z. W. (2018), "A multi-scale wavelet finite element model for damage detection of beams under a moving load", *International Journal of Structural Stability and Dynamics*, 18(6), 1850078. (SCI)

7. He, W. Y., Zhu, S. & Ren, W. X. (2019), "Two-phase damage detection of beam structures under moving load using multi-scale wavelet signal processing and wavelet finite element model", *Applied Mathematical Modelling*, 66, 728-744. (SCI)

8. Huang, M., Xu, Q., Xu, H., Ni, Y. Q., & Kwok, K. (2018), "Probabilistic assessment of vibration exceedance for a full-scale tall building under typhoon conditions", *The Structural Design of Tall and Special Buildings*, 27(15), e1516. (SCI)

9. Li, J. Y., & Zhu, S. (2018), "Versatile behaviors of electromagnetic shunt damper with a negative impedance converter", *IEEE/ASME Transactions on Mechatronics*, 23(3), 1415-1424. (SCI)

10. Liu, X.Z., & Ni, Y. Q. (2018), "Wheel tread defect detection for high-speed trains using FBG-based online monitoring techniques", *Smart Structures and Systems*, 21(5), 687-694. (SCI)

11. Ni, Y. Q., & Ye, X. W. (2018), "Special issue on structural health monitoring of high-speed railway system: Preface", *Smart Structures and Systems*, 21(5). (SCI)

12. Sahni, Y., Cao, J., & Liu, X. (2018), "MidSHM: A middleware for WSN-based SHM application using service-oriented architecture", *Future Generation Computer Systems*, 80, 263-274. (SCI)

13. Shan, S., Cheng, L., & Wen, F. (2018), "Design of non-linear-Lamb-wave-based structural health monitoring systems with mitigated adhesive non-linearity", *Smart Materials and Structures*, 27(10), 105006. (SCI)

14. Shi, X., & Zhu, S. (2018), "Nonlinear impact of negative stiffness dampers on stay cables", *Structural Monitoring and Maintenance*, 5(1), 15-38. (SCI)

15. Shi, X., Zhu, S., Ni, Y. Q., & Li, J. (2018), "Vibration suppression in high-speed trains with negative stiffness dampers", *Smart Structures and Systems*, 21(5),

653-668. (SCI)

16. Tian, Y., Liu, Z., Ge, M., Neitzel, F. (2018), "Multi-dimensional particle filter-based estimation of inter-system phase biases for multi-GNSS real-time integer ambiguity resolution", *Journal of Geodesy*, in press. (SCI)

17. Tong, L. H., Lai, S. K., Zeng, L. L., Xu, C. J., & Yang, J. (2018), "Nonlocal scale effect on Rayleigh wave propagation in porous fluid-saturated materials", *International Journal of Mechanical Sciences*, 148, 459-466. (SCI)

18. Wan, H. P., & Ni, Y. Q. (2018), "Bayesian modeling approach for forecast of structural stress response using structural health monitoring data", *Journal of Structural Engineering,* 144(9), 04018130. (SCI)

19. Wan, H. P., & Ni, Y. Q. (2018), "Binary segmentation for structural condition classification using structural health monitoring data", *Journal of Aerospace Engineering*, 32(1), 04018124. (SCI)

20. Wan, H. P., & Ni, Y. Q. (2019), "An efficient approach for dynamic global sensitivity analysis of stochastic train-track-bridge system", *Mechanical Systems and Signal Processing*, 117, 843-861. (SCI)

21. Wan, H. P., & Ni, Y. Q. (2019), "Bayesian multi-task learning methodology for reconstruction of structural health monitoring data", *Structural Health Monitoring*, 1475921718794953. (SCI)

22. Wang, J., Ding, S., Han, B., Ni, Y. Q., & Ou, J. (2018), "Self-healing properties of reactive powder concrete with nanofillers", *Smart Materials and Structures*, 27(11), 115033. (SCI)

23. Wang, J., Liu, X. Z., & Ni, Y. Q. (2018), "A Bayesian probabilistic framework for acoustic emission-based rail condition assessment", *Computer-Aided Civil and Infrastructure Engineering*, 33(1), 21-34. (SCI)

24. Wang, W. D., Jiang, S. F., Zhou, H. F., Yang, M., Ni, Y. Q., & Ko, J. M. (2018), "Time synchronization for acceleration measurement data of Jiangyin

Bridge subjected to a ship collision", *Structural Control and Health Monitoring*, 25(1), e2039. (SCI)

25. Wu, J., Wu, C., Cao, S., Or, S. W., Deng, C., & Shao, X. (2019), "Degradation data-driven time-to-failure prognostics approach for rolling element bearings in electrical machines", *IEEE Transactions on Industrial Electronics*, 66(1), 529-539. (SCI)

26. Wu, Y., & Or, S. W. (2018), "Thickness-dependent structural and electromechanical properties of (Na0. 85K0. 15) 0.5 Bi0. 5TiO3 multilayer thin film-based heterostructures", *Materials & Design*, 149, 153-164. (SCI)

27. Yan, B., Zou, Q., Dong, Y., & Shao, X. (2018), "Application of PZT technology and clustering algorithm for debonding detection of steel-UHPC composite Slabs", *Sensors*, 18(9), 2953. (SCI)

28. Ying, Z. G., & Ni, Y. Q. (2018), "Dynamic characteristics of infinite-length and finite-length rods with high-wave-number periodic parameters", *Journal of Vibration and Control*, 24(11), 2344-2358. (SCI)

29. Ying, Z. G., Ni, Y. Q., & Huan, R.H. (2018), "Vibration response characteristics of quasi-periodic sandwich beam with magnetorheological visco-elastomer core under random support excitations", *Journal of Vibration and Acoustics*, 140(5), 051017. (SCI)

30. Ying, Z. G., Yan, G. F. & Ni, Y. Q. (2018), "Semi-active bounded optimal control of uncertain nonlinear coupling vehicle system with rotatable inclined supports and MR damper under random road excitation", *Coupled Systems Mechanics*, 7(6), 707-729. (ESCI)

31. Zhang, L., Hui, K. N., San Hui, K., & Or, S. W. (2018), "3D hetero-structured cobalt oxide@ layered double hydroxide core-shell networks on Nickel foam for high-performance hybrid supercapacitor", *Dalton Transactions*. (SCI)

32. Zhang, L.H., Wang, Y. W., Ni, Y. Q., & Lai, S. K. (2018), "Online condition assessment of high-speed trains based on Bayesian forecasting approach and time series analysis", *Smart Structures and Systems*, 21(5), 705-713. (SCI)

33. Zhang, M., & Or, S. W. (2018), "Gradient-type magnetoelectric current sensor with strong multisource noise suppression", *Sensors*, 18(2), 588. (SCI)

34. Zheng, Y., & Dong, Y. (2018), "Performance-based assessment of bridges with steel-SMA reinforced piers in a life-cycle context by numerical approach", Bulletin of Earthquake Engineering, doi.org/10.1007/s10518-018-0510-x. (SCI)

35. Zhou, H.F., Yang, M., Wang, W.D., & Ni, Y.Q. (2019), "A frequency domain approach for estimating relative time lag between vibration measurement data", *Mechanical Systems and Signal Processing*, 117, 403-424. (SCI)

36. Zhou, L., Zhang, C., Ni, Y. Q., & Wang, C. Y. (2018), "Real-time condition assessment of railway tunnel deformation using an FBG-based monitoring system", *Smart Structures and Systems*, 21(5), 537-548. (SCI)

37. Zhu, Y., Ni, Y. Q., Jesus, A., Liu, J., & Laory, I. (2018), "Thermal strain extraction methodologies for bridge structural condition assessment", *Smart Materials and Structures*, 27(10), 105051. (SCI)

38. Ziaja-Sujdak, A., Cheng, L., Radecki, R., & Staszewski, W. J. (2018), "Near-field wave enhancement and 'quasi-surface' longitudinal waves in a segmented thick-walled hollow cylindrical waveguide", *Structural Health Monitoring*, 17(2), 346-362. (SCI)

(B) International Conference Papers

1. Chen, S. X., & Ni, Y. Q. (2018), "Compressive sensing for high-speed rail condition monitoring using redundant dictionary and joint reconstruction", *Proceedings of the 9th European Workshop on Structural Health Monitoring*, 10-13 July 2018, Manchester, UK.

2. Chen, S. X., & Ni, Y. Q. (2018), "Sub-Nyquist data acquisition in high-speed rail condition monitoring by means of compressive sensing", *Proceedings of the 2nd International Workshop on Structural Health Monitoring for Railway System*, 17-19 October 2018, Qingdao, China.

3. Ding, S., Han, B., & Ni, Y. Q. (2018), "Properties and application of novel pressure-sensitive sensors developed with field assisted quantum tunneling composites", *Proceedings of the 9th Cross-Strait Workshop on Structural Monitoring and Vibration Control in Civil Engineering*, 19-22 August 2018, Fuzhou, China.

4. Ding, S., & Ni, Y. Q. (2018), "Polyelectrolytes-wrapped multi-walled carbon nanotubes on long period fiber grating sensors for structural health monitoring", *Proceedings of the 6th International Symposium on Nanotechnology in Construction*, 2-5 December 2018, Hong Kong.

5. Dong, Y. & Frangopol, D. M. (2018), "Optimal adaptation of building portfolio considering climate change effects", *Proceedings of the 6th International Symposium on Reliability Engineering and Risk Management*, 31 May - 1 June 2018, Singapore.

6. Dong, Y., Wang, X., & Ni, Y. Q. (2018), "Risk-informed real time decision making of fatigue-sensitive structures within high-speed train", *Proceedings of the 2nd International Workshop on Structural Health Monitoring for Railway System*, 17-19 October 2018, Qingdao, China.

7. Dong, Y., Zheng, Y., & Li, Y. H. (2018), "Resilience assessment of highway bridges using SAM-based isolation bearings", *Proceedings of the 9th International Conference on Bridge Maintenance, Safety and Management*, 9-13 July 2018, Melbourne, Australia.

8. Kuo, C. M., Huang, C. H., Lin, C. C., Pai, Y. H., & Ni, Y. Q. (2018), "Vibration characteristics of direct-fixation track with flexible fasteners", *Proceedings of the 2nd International Workshop on Structural Health Monitoring for*

Railway System, 17-19 October 2018, Qingdao, China.

9. Li, L., Xu, K., Li, T., Zheng, K., Peng, C., Wang, D., Wang, X., Shen, M., & Mijumbi, R. (2018), "A measurement study on multi-path TCP with multiple cellular carriers on high speed rails", *Proceedings of the 2018 Conference of the ACM Special Interest Group on Data Communication*, 20-25 August 2018, New York, USA.

10. Lin, H., Liu, Z.Y., Chung, W. H., Au, D., Lu, C., Lee, K. K., Tam, H. Y. (2018), "Accelerometer based on polarization-maintaining microstructured fiber in sagnac interferometer", *Proceedings of the 26th International Conference on Optical Fiber Sensors,* 24-28 September 2018, Vaud, Switzerland.

11. Liu, X. Z., & Ni, Y. Q. (2018), "Online wheel tread defect detection for high-speed trains using a Bayesian approach", *Proceedings of the 7th World Conference on Structural Control and Monitoring*, 22-25 July 2018, Qingdao, China.

12. Liu, X. Z., Ni, Y. Q., & Zhou, L. (2018), "Condition-based maintenance of high-speed railway vehicle wheels through trackside monitoring", *Proceedings of the 2nd International Workshop on Structural Health Monitoring for Railway System*, 17-19 October 2018, Qingdao, China.

13. Ni, Y. Q., & Chen, S. X. (2018), "Compressive sensing for vibration signals in high-speed rail monitoring", *Proceedings of the 9th European Workshop on Structural Health Monitoring*, 10-13 July 2018, Manchester, UK.

14. Ni, Y. Q., & Sajjadi Alehashem, S. M. (2018), "Experimental study of the effect of MR-damper on high-speed train bogie", *Proceedings of the 7th World Conference on Structural Control and Monitoring*, 22-25 July 2018, Qingdao, China.

15. Ni, Y. Q., & Zhang, Q. H. (2018), "A Bayesian machine learning approach for online wheel condition detection using track-side monitoring", *Proceedings of the 2018 IEEE International Conference on Intelligent Rail Transportation*, 12-

14 December 2018, Singapore.

16. Shi, X., Zhu, S., Ni, Y. Q., & Li, J. (2018), "Improve ride comfort of high-speed trains using re-centering negative stiffness dampers", *Proceedings of the 7th World Conference on Structural Control and Monitoring*, 22-25 July 2018, Qingdao, China.

17. Wan, H. P., & Ni, Y. Q. (2018), "Gaussian process-based Bayesian approach to characterization of bridge strain responses using structural health monitoring data", *Proceedings of the 6th International Symposium on Reliability Engineering and Risk Management*, 31 May - 1 June 2018, Singapore.

18. Wang, X., Ni, Y. Q., & Zhou, L. (2018), "Bayesian approach for fatigue life assessment of high-speed trains using in-service monitoring data", *Proceedings of the 2nd International Workshop on Structural Health Monitoring for Railway System*, 17-19 October 2018, Qingdao, China.

19. Xia, Y. X., & Ni, Y. Q. (2018), "Time-dependent reliability analysis of bridges based on long-term strain data", *Proceedings of the 7th World Conference on Structural Control and Monitoring*, 22-25 July 2018, Qingdao, China.

20. Xu, C., & Ni, Y. Q. (2018), "A Bayesian source separation method for noisy observations by embedding Gaussian process prior", *Proceedings of the 7th World Conference on Structural Control and Monitoring*, 22-25 July 2018, Qingdao, China.

21. Xu, C., & Ni, Y. Q. (2018), "A variational Bayesian approach for temporally correlated source separation and application to thermal strain extraction of high-speed rail", *Proceedings of the 2nd International Workshop on Structural Health Monitoring for Railway System*, 17-19 October 2018, Qingdao, China.

22. Xu, C., & Ni, Y. Q. (2018), "Bayesian source separation by embedding additive Gaussian process prior and structural thermal strain extraction", *Proceedings of the 1st Five-Universities (ZJU-HKPU-UIUC-UT-UNIST) Symposium on Smart Structure Systems and Informatics*, 12-14 July 2018,

Hangzhou, China.

23. Yu, S., & Liu, Z. (2018), "Investigating the feasibility of GNSS-based ionosphere observation on a fast-moving train platform (GIFT)", *Proceedings of the 2018 Annual Forum of the International Association of Chinese Professionals in Global Positioning Systems (CPGPS)*, 13-15 July 2018, Xi'an, China.

24. Zhang, L. H., Ni, Y. Q., Lai, S. K., & Wang, S. G. (2018), "A novel machine learning technique for online health monitoring of high-speed trains", *Proceedings of the 2nd International Workshop on Structural Health Monitoring for Railway System*, 17-19 October 2018, Qingdao, China.

25. Zhang, Q. H., & Ni, Y. Q. (2018), "Online wheel condition detection using standard and heteroscedastic Gaussian process learnings", *Proceedings of the 2nd International Workshop on Structural Health Monitoring for Railway System*, 17-19 October 2018, Qingdao, China.

(C) Keynote Speeches and Invited Speeches

In 2018, CNERC-Rail team members were invited to deliver 13 keynote and invited speeches, including 7 keynote speeches and 6 invited speeches.

1. Keynote speech "Recent Techniques and Methods for Structural Health Monitoring Application" at the 1st "Belt and Road" Symposium on Innovative Technologies for Infrastructure, 9 December 2018, Shanghai, China.

2. Keynote speech "The Analysis of the Railway Real-Time Monitoring Data Based on Probabilistic Machine Learning" at the 2nd Forum on Smart Railway Technology, 17-18 November 2018, Beijing, China.

3. Invited speech "Data-Driven Damage Diagnosis & Prognosis of High-Speed Rail System" at the Forum on Era of Intelligent and Robust Railway, 16 November 2018, Taiwan.

4. Invited speech "Frontiers of Advanced Sensing Technologies in High-Speed Rail Monitoring" at the Forum on Era of Intelligent and Robust Railway, 16 November 2018, Taiwan.

5. Keynote speech "Online and Real-Time Monitoring of Rail Systems: Sensing Network and Algorithm Implementation" at the 2nd Forum on Advanced Rail Transit of the Guangdong-Hong Kong-Macau Greater Bay Area, 30-31 October 2018, Shenzhen, China.

6. Keynote speech "Experimental Studies on Digital Image Correlation and Sparse Bayesian Learning for Image Signal Processing" at the International Conference on Digital Image Correlation and Noncontact Experimental Mechanics, 15-18 October 2018, Hangzhou, China.

7. Invited speech "Bayesian Methods for Big Data from Spatio-Temporal Monitoring" at the Workshop on Big Data in Civil Engineering: Opportunity, Challenge, Practice and Trend, 21-22 September 2018, Shanghai, China.

8. Invited speech "Online Real-Time Monitoring for Metro and High-Speed Rail Systems" at the High-end Academic Forum on Smart Transportation and Safety Maintenance, 4-5 September 2018, Shenzhen, China.

9. Keynote speech "Bayesian Source Separation in Structural Health Monitoring" at the 9th Cross-Strait Workshop on Structural Monitoring and Vibration Control in Civil Engineering, 19-22 August 2018, Fuzhou, China.

10. Invited speech "Experimental Study of the Effect of MR-damper on High-Speed Train Bogie" at the 7th World Conference on Structural Control and Monitoring, 22-25 July 2018, Qingdao, China.

11. Keynote speech "Bayesian Machine Learning in Structural Health Monitoring" at the 1st ZHITU Symposium on Advances in Civil Engineering, 12-14 July 2018, Hangzhou, China.

12. Keynote speech "Compressive Sensing and Sparse Bayesian Learning in Structural Health Monitoring: Applications to Large-Scale Bridges and High-Speed Rail" at the 6th International Symposium on Reliability Engineering and Risk Management, 31 May - 1 June 2018, Singapore.

13. Invited seminar "Online Monitoring, Diagnosis and Prognosis of High-Speed Rail Systems" at China Academy of Railway Sciences, 4 January 2018, Beijing, China.

7.3 Patents

In 2018, 6 patent applications were submitted by CNERC-Rail team and 2 patents have been filed. Please refer to the detailed information as follows:

1. Chinese Patent: "Self-Centering Seismic Base Isolators" (Wang, B., Zhu, S.). Chinese Patent Application No. 201810015807.0, Application date: 8 January 2018.

2. Chinese Patent: "Self-Centering Seismic-Resistant Braces" (Wang, B., Zhu, S.). Chinese Patent Application No. 201810166828.2, Application date: 28 February 2018.

3. Chinese Patent: "A novel wave energy converter" (Shen, W.A., Zhu S., Zhu, H.P., Hu, Y.H., Xiao, Z.Z.). Chinese Patent Application No. CN201810713241.9, Application date: 3 July 2018.

4. Chinese Patent: "A Bridge Damage Quantification Method based on Deflection Influence Lines" (Chen, Z.W., Zhu, S., Cai, Q.L.). Chinese Patent Application No. CN106156501B, Application date: 31 July 2018.

5. Chinese Patent: "A Novel Wave Energy Converter" (Shen W., Zhu S., Zhu H., Hu, Y.H., Luo, H., Xiao, Z.Z.). China Model Utility Patent No.: CN201821039543.4, Publication Date: 7 December 2018.

6. Chinese Patent: "A New Design of Bumpers Embedded with High Damping Materials for Bogie Frame of High-Speed Trains" (Ni, Y.Q., Sun, Q., Lai, S.K., Yuan, M., Wang, X., Liu, X.Z., Wang, J.), Publication No. CN 109249954 A, Publication Date: January 22, 2019.

7.4 Allocation from the Research Grants Council (RGC) and Other Funding Bodies

1. “Enhancing safety, punctuality and ride comfort of railway transportation: From local metro system to global high-speed rail network” (1/1/2019-31/12/2022, RGC Research Impact Fund (RIF) Project No. PolyU R5020-18, Funding amount: HK$5,892,320.00).

2. “Model-free, response-only structural damage detection by variational sparse Bayesian learning” (1/1/2019-31/12/2021, RGC General Research Fund (GRF) Project No. PolyU 152014/18E, Funding amount: HK$632,421.00).

3. “Quantification of the uncertainty in forecasts using structural health monitoring data: A Bayesian approach” (1/1/2018-31/12/2020, RGC General Research Fund (GRF) Project No. PolyU 152024/17E, Funding amount: HK$582,000.00).

4. “Intelligent high-speed rail driven by big data and machine learning” (2/10/2018-1/10/2021, Matching Fund for CNERC-Rail, HK$15,000,000 funded by The Hong Kong Polytechnic University, Project No. 1-BBV2).

5. “Condition monitoring and intelligent data analysis techniques for operation and maintenance strategies of high-speed rail infrastructure system” (15/6/2018-14/12/2019, Hong Kong, Macau and Taiwan Science and Technology Innovation Cooperation Key Project under National Key Research and Development Plan, HK$1,227,699 funded by Ministry of Science and Technology of China, Project No. 2018YFE0190100, K-BBVZ).

6. Matching fund for “Condition monitoring and intelligent data analysis techniques for operation and maintenance strategies of high-speed rail infrastructure system” (15/6/2018-14/12/2019, Matching Grant funded by The Hong Kong Polytechnic University, HK$119,000, Project No. 1-ZVNF).

7. “Smart railway technology and applications” (12/10/2015-11/10/2018,

Matching Fund for CNERC-Rail, HK$15,000,000 funded by The Hong Kong Polytechnic University, Project No. 1-BBY5).

8. Funding support to "Hong Kong Branch of National Rail Transit Electrification and Automation Engineering Technology Research Center" (12/10/2015-11/10/2018, Innovation and Technology Fund (ITF), HK$15,000,000 funded by the Innovation and Technology Commission of HKSAR Government).

8. Expectations for Future

Over the past few years, CNERC-Rail has conducted and completed numerous research projects and collaborative industry projects. Our mission includes conducting research on condition monitoring, control, prognosis, and energy efficiency of the high-speed railway system; establishing collaborations with top-tier universities, research institutes and companies from all over the world; promoting scientific and technological deliverables self-developed by The Hong Kong Polytechnic University into high-speed railway system by actively participating in application-oriented engineering projects; and providing research guidance and technical service for China's high-speed railway industry.

In order to promote the future economic development of the Greater Bay Area, the central government of China has released the Outline Development Plan for Guangdong-Hong Kong-Macau Greater Bay Area recently. This development plan points out to build a rapid transport network in the Greater Bay Area, to focus on connecting the Mainland with Hong Kong and Macau, as well as connecting the east and west banks of the Pearl River Estuary, to build a rapid inter-city transport network mainly involving high-speed rails, inter-city railway links and high-grade motorways. The Center will seek collaborative opportunities and participate in the development of the Greater Bay Area transportation network.

Looking forward to the future, our leading task will keep focusing on becoming a world-leading smart and intelligent railway research center, and on fostering research and technical talents in the area. Supporting by the Ministry of Science and Technology of China, the Center is devoted to establishing a technologically intelligent research environment and testing platform. Relying on the Hong Kong's international platform, the Center will keep seeking opportunities to enhance the communication between China and worldwide institutions about the high-speed railway techniques, promoting our advanced techniques to the world, enhancing our competitiveness in the field of high-speed railway. The main research conducted in the Center in the coming future is employing the intelligent sensing techniques and big data methods to develop smart and intelligent rail systems and encouraging technology transfer. We also contribute our efforts to build up a modern integrated transportation system in respect of reducing operation and maintenance cost, guaranteeing the safety of rail operation and passengers, and enhancing ride comfort and service punctuality.

Appendix

A.1 Summary of Activities of CNERC-Rail in 2018

No.	Date	Activity	Location
1	4 January	Seminar in China Academy of Railway Sciences	Beijing, China
2	5 January	Meeting in China Academy of Railway Sciences	Beijing, China
3	5 January	Meeting in China Railway Corporation	Beijing, China
4	11 January	Visit to the South China Base of the National Rail Transit Electrification and Automation Engineering Technology Research Center (NEEC) of Southwest Jiaotong University	Dongguan, China
5	24 January	Visit and seminar by Professor Jian-Chun Li, University of Technology Sydney, Australia	PolyU, Hong Kong
6	26 January	Visit by Qingtie Railway Technology Corporation Ltd., China	PolyU, Hong Kong
7	2 February	Visit and seminar by Professor Chen-Ming Kuo, Taiwan Cheng Kung University	PolyU, Hong Kong
8	28 February	Visit by Prof. David Nethercot, Emeritus Professor of Imperial College London, Fellow of Royal Academy of Engineering, UK, and Prof. Yeong-Bin Yang, Honorary Dean of Civil Engineering, Chongqing University, Academician of Chinese Academy of Engineering, China	PolyU, Hong Kong
9	20 March	Visit by Mr. Bor-Kiat Ng, Chief Technology Officer (CTO) and Mr. Choon-Siong Kho from SMRT Corporation Ltd., Singapore	PolyU, Hong Kong
10	29 March	Visit and seminar by Prof. Roderick A. Smith, Emeritus Professor of Imperial College London, Fellow of Royal Academy of Engineering, UK	PolyU, Hong Kong

11	14 May	Visit by Mr. Yuen-Ming Liong, Head of Future Systems and Mr. Choon-Siong Kho from SMRT Corporation Ltd., Singapore	PolyU, Hong Kong
12	15 May	Forum on Mainland-HK Cooperation in Innovation and Technology hosted by the Hong Kong Special Administrative Region (HKSAR) Government	Hong Kong
13	29 May	Engineering Mechanics Institute (EMI) Conference	Boston, USA
14	1 June	6th International Symposium on Reliability Engineering and Risk Management	Singapore
15	8 June	Visit by Dr. Peter Ewen, Engineering Director and Mr. Peter Hui, Engineering Manager– Rolling Stock of MTR Corporation, Hong Kong	PolyU, Hong Kong
16	11 June	Visit by a delegation led by Prof. Bin Ning, President of Beijing Jiaotong University and Academician of Chinese Academy of Engineering, China	PolyU, Hong Kong
17	13 June	Luncheon hosted by the Chief Executive of the HKSAR	Hong Kong
18	10 July	9th European Workshop on Structural Health Monitoring	Manchester, UK
19	10 July	Visit by a delegation led by Mr. Han-Hua Chen, Director of Innovation and Technology Bureau of Zhaoqing Government, China	PolyU, Hong Kong
20	11 July	1st ZHITU Symposium on Advances in Civil Engineering	Hangzhou, China
21	22 July	7th World Conference on Structural Control and Monitoring	Qingdao, China
22	27 July	Visit by a delegation organized by Hong Kong Institute of Acoustics	PolyU, Hong Kong
23	8 August	Visit by Prof. Billie F. Spencer, University of Illinois at Urbana-Champaign, USA	PolyU, Hong Kong

24	9 August	Visit to headquarters of China Railway Guangzhou Group	Guangzhou, China
25	19 August	9th Cross-Strait Summer School on Monitoring and Control in Civil Engineering	Fuzhou, China
26	28 August	Visit by Thales Transport & Security HK Ltd.	PolyU, Hong Kong
27	3 September	4th International Conference on Railway Technology	Barcelona, Spain
28	4 September	High-end Academic Forum on Smart Transportation and Safety Maintenance	Shenzhen, China
29	17-19 October	2nd International Workshop on Structural Health Monitoring for Railway System (IWSHM-RS)	Qingdao, China
30	19 October	Visit by Prof. Fabio Casciati, University of Pavia, Italy and Prof. Lucia Faravelli, University of Pavia, Italy	PolyU, Hong Kong
31	22 October	Seminar by Prof. Chien-Ming Wang, University of Queensland, Australia	PolyU, Hong Kong
32	23 October	Visit by Prof. Wan-Ming Zhai, Academician of Chinese Academy of Sciences from Southwest Jiaotong University, China	PolyU, Hong Kong
33	31 October	2nd Guangdong-Hong Kong-Macau Greater Bay Area Rail Transit Forum	Shenzhen, China
34	1 November	Visit by Dr. Shih-Chi Liu, Visiting Expert from Southeastern University, China	PolyU, Hong Kong
35	2 November	Visit by a delegation of Shenzhen Government, China	PolyU, Hong Kong
36	8 November	Visit by a delegation from Shandong Jianzhu University, China	PolyU, Hong Kong
37	12 November	Seminar by Prof. Sritawat Kitipornchai, University of Queensland, Australia	PolyU, Hong Kong
38	14 November	Visit by Prof. Claus-Peter Fritzen, University of Siegen, Germany	PolyU, Hong Kong
39	15 November	Visit by a delegation from Harbin Institute of Technology	PolyU, Hong Kong

40	16 November	2018 Forum on "Era of Intelligent and Robust Railway", Tainan	Taiwan
41	17-18 November	Opening Ceremony of High-Speed Railway Committee of China Railway Society (CRS) and the 2nd Forum on Smart Railway Technology	Beijing, China
42	4 December	Seminar by Dr. Xu-Dong Qian, National University of Singapore, Singapore	PolyU, Hong Kong
43	6 December	Seminar by Dr. Sze-Dai Pang, National University of Singapore, Singapore	PolyU, Hong Kong
44	7 December	Seminar by Prof. Clive Roberts, University of Birmingham, UK	PolyU, Hong Kong
45	9 December	1st "Belt and Road" Symposium on Innovative Technologies for Infrastructure	Shanghai, China
46	12 December	Seminar by Dr. Wei Song, The University of Alabama, USA	PolyU, Hong Kong
47	21 December	Seminar by Prof. Gen-Da Chen, Missouri University of Science and Technology, USA	PolyU, Hong Kong
48	20-21 December	Visit by Delegation of Southwest Jiaotong University, China	PolyU, Hong Kong

A.2 Personnel Recruitment of CNERC-Rail in 2018

Number	name	Post	Appointment Period	
1	Weng-Hong Chung	Senior Research Fellow	1-Aug-2016	31-Jan-2018
2	Lu Zhou	Research Fellow Postdoctoral Fellow	19-May-2018 19-Nov-2017	18-Jan-2019 18-May-2018
3	Yun-Lai Zhou	Research Fellow	1-Nov-2018	30-Apr-2019
4	Chi-Fung Pun	Research Fellow	1-Oct-2017	30-Sep-2018
5	Hua -Ping Wan	Postdoctoral Fellow	17-Jan-2017	16-Jan-2019
6	Qi-Ang Wang	Postdoctoral Fellow	18-Oct-2017	17-Oct-2018
7	Seyed Masoud Sajjadi Alehashem	Postdoctoral Fellow	8-Feb-2018	7-Aug-2018
8	You-Wu Wang	Postdoctoral Fellow	7-Dec-2017	6-Dec-2018
9	Qin Hu	Postdoctoral Fellow	20-Jun-2018	19-Sep-2018
10	Xiao-Zhou Liu	Postdoctoral Fellow	26-Jul-2018	25-Jan-2019
11	Xiao Wang	Postdoctoral Fellow	21-Mar-2018	20-Nov-2018
12	Qiu-Jing Pan	Postdoctoral Fellow Research Associate	15-Nov-2017	04-May-2018
13	Bin Wang	Postdoctoral Fellow	19-Jun-2015	30-Jun-2018
14	Yang Shu	Postdoctoral Fellow	5-Dec-2017	11-Oct-2018
15	Cui-Dong Xu	Postdoctoral Fellow	1-Dec-2017	30-Apr-2018
16	Xue-Xiang Dang	Postdoctoral Fellow	1-Dec-2017	31-Jan-2018
17	Chatterjee Amrita	Postdoctoral Fellow	16-Oct-2017	15-Apr-2018
18	Su-Mei Wang	Research Associate	3-Sep-2018	31-Mar-2019
19	Xiao-Le Luan	Research Associate	15-Nov-2018	14-May-2019
20	Ying-Kin Leung	Research Associate	13-Mar-2017	20-Jan-2019
21	Xiao-Lin Wang	Research Associate	16-Jan-2018	31-Mar-2018
22	Yun-Yi Wu	Research Associate	1-Aug-2017	31-Jul-2018
23	Kin-San Wong	Research Associate	1-Aug-2016	11-Oct-2018
24	Htein Lin	Research Associate	1-Apr-2018	10-May-2018
25	Chao Zhang	Research Assistant	17-Dec-2015	16-Feb-2019
26	Liu Jiang	Research Assistant	1-Aug-2018	31-Jan-2019
27	Yu-Hung Pai	Research Assistant	3-Jul-2018	31-Dec-2018

28	Yan-Jie Zhu	Research Assistant	8-Oct-2018	7-Jan-2019
29	Yang Lu	Research Assistant	2-Oct-2018	31-Mar-2019
30	Yuan-Hao Wei	Research Assistant	2-Oct-2018	31-Dec-2018
31	Ran Chen	Research Assistant	25-Oct-2018	23-Apr-2019
32	Cao Peng	Research Assistant	12-Dec-2017	11-Oct-2018
33	Hung-Chang-Wei	Research Assistant	28-Aug-2017	11-Oct-2018
34	Singh Shubham	Research Assistant	29-Dec-2016	28-Jan-2018
35	Yi -Ting Zhang	Research Assistant	15-Sep-2017	15-Aug-2018
36	Yang Zhou	Research Assistant	29-Jan-2018	13-Jun-2018
37	Bing Tu	Research Assistant	23-Apr-2018	22-Aug-2018
38	De-Ming Zhu	Research Assistant	30-Aug-2018	14-Sep-2018
39	Zi-Mo Zhu	Research Assistant	20-Nov-2017	31-Aug-2018
40	Fu-Liao Zou	Research Assistant	7-Oct-2016	6-Jan-2018
41	Yi-Fei Zhu	Research Assistant	3-May-2018	1-Sep-2018
42	Andi Tong	Research Assistant	15-Jun-2017	14-Jun-2018
43	Jin-Yang Li	Research Assistant	20-Aug-2018	30-Sept-2018
44	Ran Wei	Research Assistant	28-Jun-2018	30-Sept-2018
45	Ming-Ji Zhang	Research Assistant	17-Jul-2017	4-Jun-2018
46	Chi-Ho Chan	Research Assistant	20-Sept-2017	31-Oct-2018
47	Shiu-Hong Mok	Research Assistant	20-Sept-2017	31-Oct-2018
48	Chi-Fai Cheung	Research Technical Assistant	2-Nov-2018	1-May-2019
49	Tai-Tung Wai	Research Technical Assistant	23-Jan-2017	22-Jan-2019
50	Wing-Hong Kwan	Research Technical Assistant	4-Oct-2017	31-Mar-2019
51	Hai-Qiu Lin	Assistant Officer	2-Jul-2017	30-Jun-2019

A.3 Media Release

理大深大牽頭組灣區交通協創中心

■理大副校長 (科研發展) 衛炳江(右三)及深圳大學校長李清泉 (右四)簽署「粵港澳大灣區現代軌道交通協同創新中心」合作備忘錄。 理大供圖

香港文匯報訊（記者　高鈺）香港理工大學聯同深圳大學牽頭，與十間院校和企業組成「粵港澳大灣區現代軌道交通協同創新中心」，以促進粵港澳大灣區軌道交通協調發展，透過共同合作發揮彼此的優勢，實現資源共享、達至聯合共贏。各機構代表於本月12日在深圳進行合作備忘錄簽署儀式。

借力創新科技 提升交通安全

據介紹，協同創新中心將因應大灣區內軌道交通建設，及安全營運與維護的重大需求，借力於創新科技，如智能感應及軌道結構健康監測系統等，以提升軌道交通基礎設施在安全運營與預警機制、性能維護、災害應急搶修與快速恢復等領域的績效。

同時，參與方亦希望藉此深化粵港澳大灣區綜合交通領域的人才培養，以及促進區內與區外軌道交通科技發展的突破與成果轉化。

理大副校長（科研發展）衛炳江表示，憑藉「一國兩制」及國際化優勢，香港具備有利條件成為國際創新科技中心，而香港的高等院校在科技發展、國際人才培養和創新創業平台搭建擔當着舉足輕重的角色。

深大校長李清泉表示，協同創新中心的成立將為粵港澳大灣區發展提供強大的助力，成員單位包括了灣區內外的高校和科研機構，反映中心有多元化的合作基礎，相信未來一定會取得很好的成果。

有關的合作備忘錄由衛炳江及李清泉代表兩間牽頭院校，與其餘十間院校和企業代表，包括：中山大學、廣州大學、北京航空航天大學、西南交通大學、澳門大學、英國倫敦帝國學院、英國伯明翰大學、中國鐵道科學研究院集團有限公司、中鐵工程設計諮詢集團有限公司及深圳市廣深港投資管理有限公司共同簽署。

簽署儀式邀請了國家教育部科技司明炬副司長、廣東省教育廳邢鋒副廳長，以及相關單位高層和行業代表出席。

Media Releases

2018.10.23

PolyU and SZU spearhead the launch of Guangdong-Hong Kong-Macau Greater Bay Area Rail Transit Joint Innovation Union

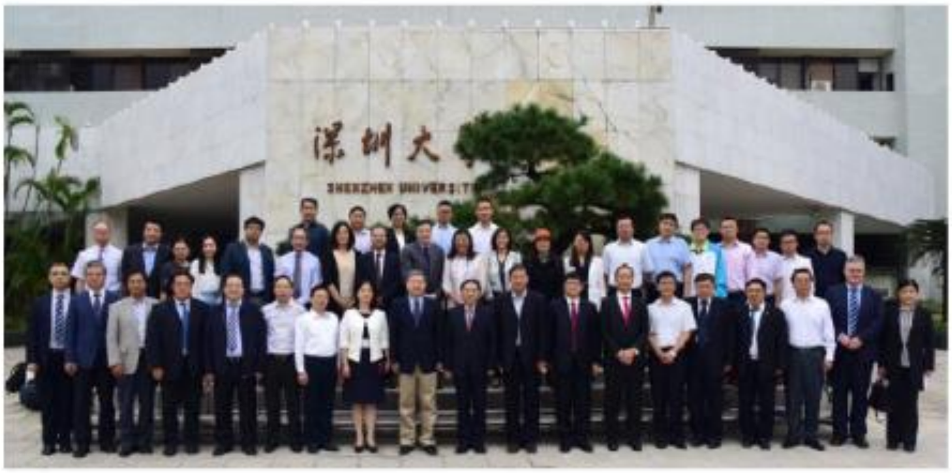
The Hong Kong Polytechnic University (PolyU) and Shenzhen University (SZU) jointly spearhead the establishment of the "Guangdong-Hong Kong-Macau Greater Bay Area Rail Transit Joint Innovation Union" (the Union), upon signing a memorandum of understanding (MoU) on 12 October 2018 with 10 other universities and enterprises. The Union aims to advance research in the area of rail engineering, thus contributing to the development of the rail transit system within "Guangdong Hong Kong Macau Greater Bay Area" (GBA).

The Union will serve as the joint innovation platform of rail transit in GBA through facilitating research collaborations between universities and industries. The Union will seek research and technological breakthroughs to cater to the tremendous needs of safe operations and maintenance of the rail transit in GBA. The research efforts will focus on smart sensing and health monitoring of rail infrastructure, safety alert mechanism, disaster resilience program, crisis contingency and recovery plan etc., to promote safe operation and maintenance of rail transit system. The Union will take advantage of the academic resources and strengths of the participating parties to foster talent nurturing in GBA, and to promote technology transfer as well as commercialisation of the research outcomes within and beyond GBA.

Ir. Professor Alexander Wai, Vice President (Research Development) of PolyU, said, "Leveraging the 'one country, two systems' principle and the distinctive feature of internationalisation, Hong Kong has the full advantage to become an international innovation and technology hub. Hong Kong universities play a pivotal role in the development of science and technology, grooming international talents and facilitating innovation and entrepreneurship. PolyU has been actively participating in various national research projects over an extended period, from space missions and high-speed rail in China to the recent research collaborations in GBA for technological advancement including the establishment of the first Biotechnology and Translational Medicine research platform, Joint Center for Immunotherapy and the Supercomputer Union. Capitalised on the strengths of the participating institutions, we look forward to seeing more collaborations in the Union so that innovative technologies can be broadly applied in rail transit system."

Professor Li Qing-quan, President of SZU, said that the launch of the Union will provide a strong boost to the developments of GBA. The Union comprises of universities and research institutions within and beyond GBA, indicating a strong base for diversified cooperation. He believes the Union will bring about profound outcomes in the R&D of the rail transit system. Professor Du Yan-liang, Academician of China Engineering Academy also remarked that the Union will take into account the needs for rail transit development within GBA in developing its research agenda with a view to facilitating the development of smart transportation system.

The MoU was jointly signed by Ir. Professor Alexander Wai, Vice President (Research Development) of PolyU and Professor Li Qing-quan, President of SZU as representatives from the two leading units, as well as the representatives from the 10 partners including Sun Yat-sen University, Guangzhou University, Beihang University, Southwest Jiaotong



University and University of Macau of China, Imperial College London and University of Birmingham of the United Kingdom, China Academy of Railway Sciences Corporation Limited, China Railway Engineering Consulting Group Corporation Limited and Shenzhen Guangshengang Investment Management Corporation Limited. Mr Ju Ming, Associate Director, Department of Science and Technology, Ministry of Education and Mr Xing Feng, Deputy Director, Department of Education, Guangdong Province also attended the signing ceremony together with many government officials and industry leaders.

About the 12 participating parties of the Union:

Striving Ahead
Rekindling Hope

Promoting Technology Transfer

102. There is gifted and outstanding scientific research talent in various local universities. To fully unleash our strengths in scientific research and promote technology transfer as well as the realisation of R&D findings, funding for three relevant schemes under the I&T Fund will be doubled. The maximum annual funding for the Technology Transfer Office of each university will be increased from the existing $4 million to $8 million; the maximum annual funding for each specified university under the Technology Start-up Support Scheme for Universities will also be increased from the existing $4 million to $8 million; and the annual funding for each State Key Laboratory and each Hong Kong branch of the Chinese National Engineering Research Centre will be increased from the existing $5 million to $10 million to support scientific research and commercialisation of outputs.

Ni, Yiqing [CEE]

From: Nicholas YANG <nick.yang@itb.gov.hk>
Sent: Wednesday, October 10, 2018 1:14 PM
To: Ni, Yiqing [CEE]
Subject: 2018 Policy Address (Innovation and Technology)

Dear Professor Ni,

The Chief Executive is delivering her second Policy Address today. Innovation and technology ("I&T") has continued to be high on her agenda. I am glad to inform you that she is again making substantial investment in the development of I&T. Set out below are the key new initiatives to be implemented by the Innovation and Technology Bureau ("ITB") –

(a) Investing $4 billion in promoting new manufacturing, composing of $2 billion for setting up a "Re-industrialisation Funding Scheme" to fund manufacturers on a matching basis to set up smart production lines in Hong Kong, and another $2 billion for developing facilities in Industrial Estates for conducting advanced manufacturing;
(b) Doubling the funding: (i) for the technology transfer offices of designated universities; (ii) provided under the Technology Start-up Support Scheme for Universities; and (iii) provided to the State Key Laboratories and Hong Kong branches of Chinese National Engineering Research Centre, to promote technology transfer and realisation of R&D findings;
(c) Organising a "City I&T Grand Challenge" to create a fervid I&T atmosphere in the community;
(d) Establishing a Smart Government Innovation Lab in the Office of the Government Chief Information Officer (OGCIO) to promote Smart Government. The OGCIO will invite the industry to put forward proposals for information technology application and product proposals for various public services, as well as arrange trials and technology testing for suitable proposals, thereby helping government departments to formulate innovative measures for service delivery, and creating business opportunities for local start-ups and SMEs;
(e) Enhancing the GovHK portal by introducing artificial intelligence and chatbot functions to facilitate the search and use of e-Government services, and stepping up the implementation of e-Government with the application of eID; and
(f) Allocating an additional $500 million to intensify the use of technology by government departments to provide a better service.

For other I&T initiatives announced in this year's Policy Address, please see the full text at:

(Chinese)
https://www.policyaddress.gov.hk/2018/chi/policy.html

(English)
https://www.policyaddress.gov.hk/2018/eng/policy.html

Separately, we will continue to work hard on the various key initiatives rolled out in the past year. For example, the legislative work for providing enhanced tax deduction for local R&D expenditure

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will soon be completed, so that qualifying R&D expenditure incurred on or after 1 April 2018 will be eligible for tax deduction of up to 300 %. We are also actively engaging top universities and research institutes worldwide to recruit them to the two R&D clusters to be set up in the Hong Kong Science Park.

I&T development cannot succeed without the support and participation of our partners in the industry, academia and research institutes. I appeal to you for continued support for the Policy Address, as well as the work of ITB. Please give us a call if you need any further information.

Best regards,

Nicholas Yang
Secretary for Innovation and Technology

2

攞正牌「科水」 利洽談合作

倪一清指「過河」意義重大 料外界信心興趣大增

國家主席習近平作出重要指示，要求大力推動內地和香港科技合作，讓香港高等院校及科研機構獲納入國家科技計劃，科研經費亦可直接「過河」資助，讓香港創科進入新時代。率先受惠的理工大學國家軌道交通電氣化與自動化工程技術研究中心香港分中心，專研高鐵監測相關技術，中心主任倪一清近年積極將技術推廣應用至新加坡及巴西等地，他接受香港文匯報專訪時指，分中心現時可「名正言順」獲國家科技部直接支持，科研項目獲國家認可，對日後與內地單位以至海外機構洽談合作肯定有利，意義遠較實際金額更為重大。

■香港文匯報記者 姜嘉軒

習近平主席支持香港成為國際創科中心，其中本港「16+6」國家重點夥伴實驗室及國家工程技術分中心，在早前的先導項目下，已率先各獲科技部100萬元人民幣直接資助。

倪一清表示，雖然「16+6」均須獲科技部批准才可成立，亦要每年向科技部匯報情況，分享工作進度，但夥伴實驗室及分中心運作過往完全依賴香港資金，以該中心為例，每年經費主要來自創新科技署的500萬元及理大校方的一比一配對，即合共約1,000萬元。

他指，由於以往並沒有直接經費資助，「即使我們分中心確涉及科技部管理，外界卻可能抱持『有錢才有管理權責』的誤解，對分中心的工作或有保留。」

昔分享有顧忌 身份未必對等

倪一清解釋，分中心所進行的高鐵研究領域，往往涉及一些機密資訊，以往跟內地鐵路公司接洽合作時，對方多會抱謹慎態度查詢分中心來歷，包括查問資金來源，分享資訊時亦可能有所顧忌，雙方於身份上未必對等。

這情況或隨着100萬元人民幣資金到位迎來轉變。雖然作為先導，有關金額未算龐大，但倪一清看到背後的重大意義，更與記者分享這筆資金的項目任務書內容：其中清楚顯示，分中心申請項目為國家重點研發計劃的「港澳台科技創新合作重點專項」，管理機構為國家科技部領導下的中國科學技術交流中心，「這好比是給分中心一個名正言順，未來領合作肯定更方便，外界亦更清楚理解我們。」

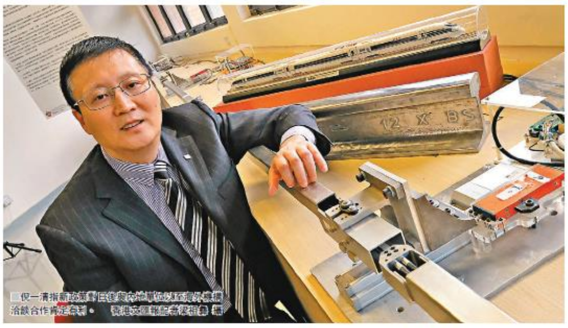
倪一清團隊近年一直有參與中國高鐵國際化的工作，將相關技術與系統輸出海外，向外國推廣香港的創新科技。其中由他研發的光纖光柵傳感器已出口至新加坡，應用於當地的鐵路系統；另在2016年里約奧運期間，倪一清團隊亦獲邀請，監測里約地鐵列車的營運性能。

他笑言，分中心「名正言順」獲國家科技部直接資助的消息一出後，已即時將詳情轉發給所有合作夥伴，「他們對我們的信心及興趣肯定會大增」。

可主導國家科研項目

倪一清又說，以往香港學者必須要透過大學於內地設的研究院申請國家科研經費，亦可能面臨類似困境，「這容易予人『非全心全意』投入的不良印象，對申請不利」。在科技部新政策下，項目經費不單可「過河」，香港科學家更可以首席研究員（PI）身份主導國家科研項目，科研界都大感鼓舞。

他並透露，自己已計劃跟理大另一教授合作申請「國家自然科學基金」項目，資助額上千萬計，正摩拳擦掌迎接新機遇。



■倪一清指新政策對日後與內地單位以至海外機構洽談合作肯定有利。 香港文匯報記者梁祖彝 攝

港須背靠祖國 累積高鐵經驗

■倪一清強調分中心工作是應中國高鐵需求而做，充分體現「國家所需，香港所長」。 香港文匯報記者梁祖彝 攝

香港文匯報訊（記者 姜嘉軒）中國高鐵發展一日千里，而高鐵香港段亦將於短期內開通，正式與國家接軌。倪一清分享經驗指，分中心的高鐵相關研發項目絕不可能由香港「單打獨鬥」，必須要背靠祖國，積極爭取新技術到內地不同高鐵路線試用，累積經驗及數據，提升競爭力與外國一爭長短。

理大國家軌道交通技術研究香港分中心的鐵路工程團隊，過去與西南交大合作開發多項高鐵新技術，包括能夠發揮高鐵「醫生」作用的光纖監察裝置，安裝在列車及路軌等多個位置，實時監察列車運行狀況，取得數據以評估高鐵的勞損狀況，以及會否存在出軌風險，加強高鐵的舒適度及安全性。

3D打印研路軌壽命

倪一清分享分中心最新工作進展時指，他們目前正應中國鐵路總公司要求，積極探究3D打印技術應用於高鐵發展的可能性，方向包括透過3D打印技術，將RFID射頻識別與傳感器結合，從而製造新型傳感設備；以3D打印技術將兩種不同智能流體（smart fluid）材料結合，有關物料只要通電就會變為固態，密度改變後能有效起減震、減噪作用，亦有助減輕路軌設磨情況，加強路軌壽命。倪一清強調，這些都是真正應中國高鐵需求而做的，充分體現「國家所需，香港所長」。

他續指，隨着高鐵香港段即將通車，未來希望能向有關部門提案爭取合作空間，但從科研與累積測試經驗角度而言，加強與內地協作仍然是不二之選。「畢竟高鐵香港段只有短短26公里，很多環境狀況都難以在這裡測試」，相比之下國家地大物博，能在不同路線取得氣候溫差等環境因素，及對鐵路造成影響的數據，「例如路面結冰有機會將路軌拱起，構成危險，香港根本不可能出現這類情況」。

倪一清指，分中心現已做出感應器供內地試用監察上述情況，下一步則是研究能否開發扣件（Fastener）直接解決路軌拱起問題，可見只有不斷「實戰」，才是促使科技進步的最佳法門。

國家新政策銳意加強兩地合作，倪一清認為在此契機下香港科學家可累積更多數據與經驗，加強國際競爭力，「如果我們到海外爭取研究項目時，對方一定會查閱你的履歷，累積研發高鐵技術與系統經驗愈多，成數肯定更高」。

香港 新聞 2015年11月5日 星期四 香港商報 Hong Kong Commercial Daily http://www.hkcd.com A14

國家科技部批准 研高鐵及鋼材技術

理大設國家級科研中心

【香港商報訊】香港理工大學獲得國家科學技術部批准，成立兩所國家工程技術研究中心香港分中心：國家軌道交通電氣化與自動化工程技術研究中心香港分中心；及國家鋼結構工程技術研究中心香港分中心。未來3年，每所分中心將分別獲香港創新科技署每年500萬港元的資助上限，及理大提供的一比一配對基金支持其研究工作，為國家和香港科研作出貢獻。

夥拍內地推動應用科技發展

智能鐵研中心設3個研究室

向世界展示國家鋼材技術

一、國家重點實驗室夥伴實驗室	實驗室主任	國家科學技術部批准年份
港大		
新發傳染性疾病國家重點實驗室夥伴實驗室	管軼、袁國勇	2005
腦與認知科學國家重點實驗室夥伴實驗室	沈伯松	2005
肝病研究國家重點實驗室夥伴實驗室	吳呂愛蓮	2010
合成化學國家重點實驗室夥伴實驗室	支志明	2010
生物醫藥技術國家重點實驗室夥伴實驗室	徐愛民	2013
中大		
華南腫瘤學國家重點實驗室夥伴實驗室	孔祥復	2006
農業生物技術國家重點實驗室夥伴實驗室	張建華	2008
植物化學與西部植物資源持續利用國家重點實驗室夥伴實驗室	梁秉中	2009
消化疾病研究國家重點實驗室夥伴實驗室	沈祖堯	2013
科大		
分子神經科學國家重點實驗室夥伴實驗室	葉玉如	2009
先進顯示與光電子技術國家重點實驗室夥伴實驗室	郭海成	2013
城大		
毫米波國家重點實驗室夥伴實驗室	陳志豪	2008
海洋污染國家重點實驗室夥伴實驗室	林群聲	2009
理大		
超精密加工技術國家重點實驗室夥伴實驗室	李榮彬	2009
手性科學國家重點實驗室夥伴實驗室	黃國賢	2010
浸大		
環境與生物分析國家重點實驗室夥伴實驗室	蔡宗葦	2013

二、國家工程技術研究中心香港分中心名稱	港分中心主任	成立年份
香港應用科技研究院		
國家專用集成電路系統工程技術研究中心香港分中心	湯復基	2012
理大		
國家鋼結構工程技術研究中心香港分中心	鍾國輝	2015
國家軌道交通電氣化與自動化工程技術研究中心香港分中心	倪一清	2015
城大		
國家貴金屬材料工程技術研究中心香港分中心	呂堅	2015
科大		
國家人體組織功能重建工程技術研究中心香港分中心	唐本忠	2015
國家重金屬污染防治工程技術研究中心香港分中心	陳光浩	2015

資料來源：特區政府新聞公告　　製表：記者 姜嘉軒

研發光纖技術 提升高鐵安全水準

理翘科技

倪一清教授

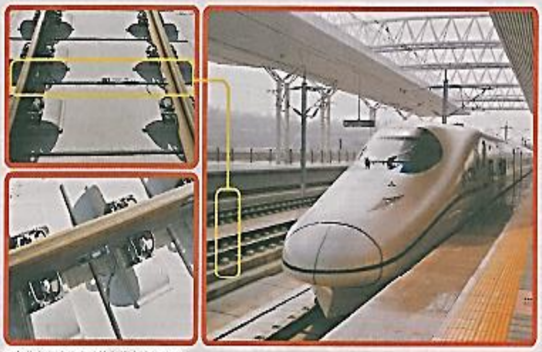
近年中國高速鐵路（高鐵）技術突飛猛進，正好配合國家發展的需要。京津城際高鐵、武廣高鐵、鄭西高鐵、福廈高鐵、滬寧高鐵和滬杭高鐵之後，北京至上海全長1318公里的京滬高鐵亦已於去年11月完成全線鋪軌工作。至今，國家的重點城市已大致可靠高鐵緊密相連，千里之遙亦變得近在咫尺。

自諾貝爾獎得主高錕教授於1966年發表「光通訊」基礎理論至今，光纖技術的應用層面已跨越通訊領域。香港理工大學的科研人員悉心研究，將光纖技術轉化為不同功能的傳感器，並將它們用於鐵路安全監測。這項研究對國家發展全國高鐵網絡有極其重大意義。

京滬高鐵的設計時速350公里，最高運營時速可達380公里。今年1月，中國自行研製的新一代「和諧號」CRH380BL高速動車組在京滬高速鐵路先導段運行試驗中創造了每小時487.3公里的世界鐵路運行試驗的最高速度，實在是中國人的驕傲。中國已成為當今世界高鐵發展最快、營運里程最長、營運速度最高、在建規模最大的國家。

傳感器小巧可抗電磁干擾

據近日媒體報載，中國國務院為貫徹自主創新的方向，正在考慮為七大戰略性新興產業投入多達1.5萬億美元的投資，其中高鐵科技能將成為七大戰略性新興產業計劃的重中之重，期望這些技術產業成為國家未來十年經濟增長的新支柱，並且在國際上居於領導地位。



■安裝在高速鐵路鋼軌上的光纖傳感器

事實上，高鐵亦已成為其他國家新一輪的發展方向。美國總統奧巴馬在上月發表的國情咨文，便提出要在未來25年內使高速鐵路覆蓋全美80%的目標。為實現這一目標，副總統拜登於本月8日在費城宣布，美國政府將在未來6年內投資530億美元發展高速鐵路網。由此可見，發展高速鐵路網對發達國家和發展中國家都是同等重要。

香港理工大學的科研工作一直以應用為本，講求實用性，並積極配合社會、國家和世界的實際需要。順應國家全力發展高鐵的形勢，研究人員把握機遇，善用他們在光纖領域已經取得的研究和應用成果，針對高鐵安全運行監測研發各種智能傳感器，提升高鐵的營運效率和安全程度。

理大電機工程學系的譚華耀教授和何兆豪教授早於2002年已開始研發建基於先進光纖傳感技術的智能鐵路監測系統，並與當時的九廣鐵路公司開展了非常密切的合作研究。傳統的電訊號傳感器由於存在易受電磁干擾、易被雷擊、接線繁複、體積較大、難以多點連續監測等缺點，以致未能在鐵路系統中得到廣泛應用。譚教授和何教授採用性能卓越的光纖光柵傳感元件研發出智能鐵路監測系統，它們具有抗電磁干擾、小巧輕盈、便於安裝、可多點連續監測、可多路傳輸等顯著優點，大大提升了其於鐵路系統上的實用性，對鐵路的營運效率和安全保障有非常正面的影響。該系統其後更成功申請兩項美國專利，並獲得第三十二屆日內瓦國際發明展金獎。

2007年，「理大──九鐵智能鐵路研究實驗室」成立，使該系統的實時監測性能、安裝可行性、實用性及可靠度等得到進一步的實地檢驗。時至今日，該系統一直應用於連接香港與內地的香港鐵路東鐵線及其他鐵路線的火車和軌道安全監測，這也是全球首個應用於鐵路實時監測的光纖傳感系統。

跨學科研究團隊集思廣益

由於高速鐵路技術涉及不同學科與研究領域，理大去年組成了鐵道工程跨學科研究的合作團隊，以便能為國家作出更加切合實際需要的貢獻。這一合作團隊的成員包括來自該校電機工程學系、土木及結構工程學系、機械工程學系、電子及資訊工程學系、電子計算學系、工業中心的研究和技術人員。

合作團隊在過去幾個月已開發了各種基於光纖和壓電材料的傳感器，比如應變計、加速度計、風壓計、傾斜儀、水準儀、溫度傳感器、濕度傳感器，可用於高速鐵路車廂、鋼軌、路基和鐵路橋的震動、疲勞、空氣動力穩定性、裂縫及其他結構損傷的實時監測。部分傳感器已被安裝於高速鐵路系統中，效果良好。

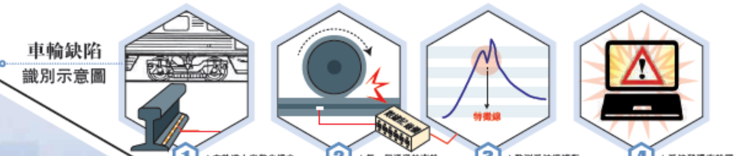
與此同時，一個非常有意義的高速鐵路火車從出廠到上線的「全程監測之旅」也正在計劃中，有關計劃將可進一步提升國家在世界高鐵發展方面的領導地位。

該合作團隊最近與西南交通大學、北京交通大學、大連交通大學等內地院校簽訂了合作協議，進一步推動智能監測技術在高速鐵路中應用。此外，理大正聯同設有高鐵研究中心的六所內地大學一起籌辦於今年7月在香港舉行的「高速及城際鐵路國際會議」，在學術和應用層面探索這一重要議題。

作者為香港理工大學教授、理大鐵道工程跨學科研究召集人

港研光纖傳感器「把脈」輪軌勞損

倪一清：智能化守護高鐵安全



▲在軌道上安裝光纖光柵傳感器，當列車通過時，光纖以反射光波長變化反映感應值

▲每一個通過的車輪造成光柵對應反射波長，感應數據實時傳回數據記錄儀

▲監測系統根據對比預先設定的正常波長，瞬間可發現異常波段

▲系統發現車輪異常即發出危險警報，並能精準定位到問題車輪

2016年是國家高鐵「走出去」計劃元年，從雅萬高鐵到坦贊鐵路，從俄羅斯的嚴寒山地到美國的酷熱沙漠，都將看到中國高鐵的身影。為保證高鐵可在不同環境下安全運行，香港理工大學國家軌道交通電氣化與自動化工程技術研究中心香港分中心研發的「光纖光柵傳感器」將隨高鐵一起奔馳四方、走出國門，擔當「隨車醫生」與「安全衛士」，為千萬人的出行保駕護航。

科技報國 香港英才(二)

大公報記者 胡岸、陸穗文

▲小巧的光纖光柵傳感器可安裝於軌道上

資料圖片

▲香港理工大學國家軌道交通電氣化與自動化工程技術研究中心香港分中心研發的「光纖光柵傳感器」為高鐵保駕護航

資料圖片

▼光纖光柵傳感監察示範裝置

大公報記者胡岸攝

倪一清簡介

理工大學土木及環境工程學系教授、鐵道工程跨學科研究召集人、國家軌道交通電氣化與自動化工程技術研究中心香港分中心主任。先後參與青馬大橋、昂船洲大橋等結構健康監測系統設計；主持江陰大橋、青島海灣大橋、廣州新電視塔等內地大型工程項目的結構監測系統設計等。其研發的各類監測系統曾多次獲得日內瓦國際發明展金獎、特別大獎和中國國際工業博覽會金獎等獎項。

「火眼金睛」檢測京滬高鐵

「守株待兔」小身材大本領

整體性「智造」高鐵谷出口

A.4 List of Equipment in 2018

Description	Quantity
Strut Profile	1
Digital Graphical Sampling Multimeter	1
AC Adapter for EDX-100A	1
Chemical Vapor Deposition System	1
1:5 Scaled Down 3D Printing Bogie	1
FOCS and Fixing Ring	1
Weather Transmitter WXT539 Series	1
1:2 Scaled Down 3D Printing Bogie	1
Rail Damper	1
1:2 Aluminium Railroad for HSR Project	2
Hanging System for 1:2 Bogie	1
Altas RFID Antenna	1
Vibration Table	1

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