Manufacture and Testing of Acoustic Microfluidic Chip

LU Xiaolong, *WEI Ying*, *OU Huan*, *ZHAO Cong*, *SHI Lukai*, *QIAN Feng*
(State Key Laboratory of Mechanics and Control of Mechanical Structures, Nanjing University of Aeronautics and Astronautics Nanjing, 210016, China)

Abstract The manufacturing and testing methods of an acoustic manipulated microfluidic chip are introduced in this study. The basic structure of the rigid microfluidic chip is designed based on the working principle and functional requirements of the acoustic microfluidic chip. The open boundary microchannel made of polymethyl methacrylate (PMMA) is fabricated by laser cutting. The machining of microchannel with closed boundary is realized by computerized numerical control (CNC) fine carving method. The rigid microchannel and substrate are bonded at room temperature by photocuring ultra violet (UV) adhesive. Pumpless injection of fluid is enabled by using surface modification technology and capillary action. The influence of different manufacturing technology and parameters on the micro-channel morphology is investigated. According to the requirements of the acoustically controlled microparticles, the working frequency of the acoustic platform is selected by comprehensive simulation analysis, impedance test, and doppler laser vibration measurement. This kind of microfluidic chip has the advantages of low cost, high processing efficiency, and ease-to-use to meet the needs in diverse applications of micro/nano assembly, micro/nano-manufacturing, and biochemical detection, etc.

Keywords microfluidic; micromachining; piezoelectric actuation; ultrasound; micromanipulation

Fault Diagnosis of Gearbox Compound Fault Based on Multi-scale Compound Regularized Convolutional Sparse Coding

ZHOU Haoxuan[1], *WEN Guangrui*[1,2], *HUANG Xin*[1], *DONG Shuzhi*[1], *ZHOU Xin*[1]
(1. School of Mechanical Engineering, Xi'an Jiaotong University Xi'an, 710049, China)
(2. School of Mechanical Engineering, Xinjiang University Urumqi, 830047, China)

Abstract In modern mechanical equipment transmission systems, bearings and gears are prone to local fatigue failures. Load fluctuations caused by typical failures of a single component are very likely to cause secondary fatigue failures of other components, making the mechanical transmission system present a multi-component composite failure state. Aiming at the problem of compound fault diagnosis of bearings and gears in gearbox transmission systems, this paper proposes a convolutional sparse coding (MCRCSC) separation diagnosis algorithm based on multi-scale convolution kernel matching compound regularization. First, the model assumptions are made based on the sparseness and scale characteristics of the typical composite faults of gearbox bearings and gears. Then the concepts of multi-scale convolution kernel and convolution sparse composite regularization are proposed in terms of the signal scale and distribution characteristics of different faults, and the multi-component convolution separation is accordingly established. In the model, the optimization equation after frequency domain conversion is decomposed into sub-problems by alternating direction multiplier (ADMM) optimization architecture and alternately solved, and the corresponding fault frequency distribution is obtained by spectrum analysis of the fault signal after separation and convolution reconstruction. Simulation analysis based on model assumptions and actual gearbox fault simulation experiments show that the proposed algorithm has excellent fault separation and diagnosis capabilities under random noise and harmonic interference.

Keywords convolutional sparse coding; multi-scale convolution kernel; compound regularization; mechanical compound failure; gearbox

Aerodynamic Interference Effect of Two Rounded Corner Arc Triangular High-Rise Buildings in Tandem Configurations

DING Tong, *CHEN Shuifu*

(College of Civil Engineering and Architecture, Zhejiang University Hangzhou, 310058, China)

Abstract The aerodynamic force of two rounded corner arc triangular high-rise buildings in tandem configurations has been studied with the wind-tunnel tests. The effect of different arrangements and relative distances on the layer drag coefficients, layer lift coefficients and overturning moment coefficients power spectrum of the disturbed building is analyzed. The results show that the interference effect of the mean layer drag and lift coefficients is mainly incarnated in shielding effect, which is relatively stronger when the arc surface of the disturbing building is windward. The mean layer drag coefficients decrease as the spacing ratio decreases. When the buildings are symmetrical about the flow direction, the mean layer lift coefficients are close to 0, and the influence of spacing is small. The flow around the top of the disturbing building makes the shielding effect weak, relatively increasing the mean and fluctuating layer wind force coefficients near the top. When the arc surface of the disturbing building is windward, the vortex shedding in the wake significantly affects the disturbed building, greatly increasing the fluctuating wind load when the spacing ratio is small, and making the peak frequency of the across-wind overturning moment coefficients power spectrum controlled by the wake vortex shedding frequency.

Keywords high-rise buildings; interference effect; wind tunnel test; tandem configuration; triangular section

Axle Box Bearing Fault Diagnosis Based on Average Autocorrelation and Optimized VMD

CHEN Chunjun[1,2], *ZHOU Linchun*[1], *YANG Lu*[1]

(1. School of Mechanical Engineering, Southwest Jiaotong University Chengdu, 610031, China)

(2. Technology and Equipment of Rail Transit Operation and Maintenance Key Laboratory of Sichuan Province Chengdu, 610031, China)

Abstract In order to solve the problem that the non-stationary characteristics of the axle box bearing vibration acceleration signal and the background noise during the operation of the electric multiple units difficult to extract the fault characteristics, a fault diagnosis method of axlebox bearings based on average autocorrelation is proposed combined with parameter optimization variational mode decomposition (VMD). Firstly, the average autocorrelation to reduce the noise of the original signal is used to enhance the fault cycle information. Then the fault characteristic frequency energy ratio is selected as the fitness function, and Harris hawks optimization (HHO) is utilized to optimize the number of modal components and the secondary penalty coefficient of VMD to achieve the adaptive decomposition of the noise reduction signal, for extracting the best modal component. Finally, its squared envelope spectrum is calculated for fault analysis. Through simulation and test signals analyses, the results show that the method can effectively reduce the influence of background noise, stably extract the components of periodic fault impact, and realize the accurate diagnosis of axle box bearing fault.

Keywords electric multiple units (EMU); axle box bearing; fault diagnosis; average autocorrelation; variational mode decomposition (VMD); Harris hawks optimization

Analysis of Mechanical Properties of Bag-Type Molecular Spring Vibration Isolator

JIN Yang, *CHEN Weidong*, *CHEN Qian*, *TENG Handong*

(State Key Laboratory of Mechanics and Control of Mechanical Structures, Nanjing University of Aeronautics and Astronautics Nanjing, 210016, China)

Abstract Combined with the deformation analysis of the capsule and the process of water molecules invading the hydrophobic microholes, the mechanical model of the molecular spring isolator is established, and the force displacement relationship of the isolator is deduced. The mechanical model is verified by quasi-static test, the influence factors of the performance of the isolator are analyzed by simulation and experiment. The results show that the theoretical and experimental results are in good agreement. The molecular spring isolator exhibits high, low and high segmental stiffness, and the stiffness of the stage Ⅱ is greatly reduced compared with that of the stage Ⅰ. The parameters such as pore diameter, contact angle and pore volume at the micro level, material consumption and sodium chloride solution concentration at the macro level have an impact on the stage II of the vibration isolator. Adjusting these parameters can flexibly adjust the performance of the vibration isolator and adapt to different engineering needs.

Keywords bag-type; molecular spring; segmental stiffness; vibration isolation

Fault Diagnosis of Rolling Bearing Based on Adaptive Variational Mode Decomposition and Second-Order Frequency-Weighted Energy Operator

WANG Xiufeng, *WEN Jun*, *NI Zexing*, *WU Renqiong*

(School of Mechanical Engineering, Xi′an Jiaotong University Xi′an, 710049, China)

Abstract In view of the problem that the vibration signal of rolling bearing often contains harmonics, Gaussian white noise and non-periodic transient impact components, which makes it difficult to extract fault features, a fault diagnosis method is proposed based on the combination of adaptive variational mode decomposition (AVMD) and second-order frequency weighted energy operator (SFWEO). The method firstly determines the number of modes and penalty factors adaptively according to different signals, and decomposes the original signal with parameter-optimized variational mode decomposition (VMD) to obtain multiple instrinsic mode function (IMF). Secondly, the time-frequency weighted kurtosis of each mode component is calculated to select the best IMF according to the time-frequency weighted kurtosis maximization criterion. Finally, the second-order frequency weighted energy operator is used to demodulate the best IMF. Simulation and experimental results show that the proposed method overcomes the problem that the resolution accuracy of the traditional VMD algorithm is greatly affected by the parameters, which leads to the signal over-decomposition or under-decomposition. At the same time, the second-order frequency-weighted energy operator has a good suppression effect on the interference components in the signal, and effectively improves the diagnostic accuracy.

Keywords rolling bearing; fault diagnosis; variational modal decomposition; second-order frequency-weighted energy operator

Coal-Rock Recognition of Intelligent Mining Face Based on the Fusion of Image and Laser Point Cloud

SI Lei[1], *WANG Zhongbin*[1], *LI Jiahao*[1], *WEI Dong*[1], *LIANG Bin*[1,2], *XIAO Junpeng*[3]

(1. School of Mechatronic Engineering, China University of Mining and Technology Xuzhou, 221116, China)

(2. Xuhai College, China University of Mining and Technology Xuzhou, 221008, China)

(3. Inner Mongolia Zhahanur Coal Industry Co., Ltd. Tongliao, 029100, China)

Abstract In order to improve the intelligent level of coal mining face, this paper proposes a novel coal-rock recognition method based on the fusion of image and laser point cloud. Firstly, the three-dimensional reconstruction is used to realize the construction of coal-rock image point cloud containing color information and cutting texture features. Secondly, a coal-rock point cloud registration algorithm based on improved iterative closest point (ICP) algorithm is proposed to improve the search speed and accuracy between point pairs. Then, a coal-rock recognition method based on improved regional growth algorithm is designed. The effectiveness of the improved measures is verified by simulation analysis. The self-established coal-rock cutting experimental system is set up, and the experimental comparison and analysis of the improved ICP and region growth algorithm are carried out. The results indicate that the point cloud data segmentation effect of the proposed method is the best and the accuracy of coal-rock recognition can reach to 92.95%. The field test is carried out in the underground coal face, which further proves the practicability and feasibility of proposed coal-rock recognition method.

Keywords coal-rock recognition; image point cloud; laser point cloud; point cloud registration; point cloud segmentation

Train-Bridge Coupling Dynamic Analysis of Multi-line Subway Viaduct

WU Jun[1], *SI Huilong*[1], *DONG Kai*[1], *MIAO Tong*[2], *BIAN Yichun*[1]

(1. Highway College, Chang′an University Xi′an, 710064, China)

(2. Guangzhou Metro Design Institute Co., Ltd. Guangzhou, 510010, China)

Abstract In order to analyze the vehicle-bridge coupling of viaducts for multi-line subway, this paper establishes a metro train-bridge coupling model based on ANSYS′s parametric design language (APDL), for considering the operation of single and double lines. The prototype bridge is a three-span continuous viaduct for four-line subway, and the train type is the type-B metro train of six cars (4 motor cars and 2 trailers cars). The dynamic response of the viaduct for metro train operations along different single and double lines is analyzed. The results show that the influence of metro train on the viaducts′ lateral displacement and acceleration is small. When the double-line trains run simultaneously in opposite direction, the vertical displacement and acceleration responses of the bridge are greater than the case of running along a single line, and the internal forces of the bridge′s critical section is approximately 67%～99% of the sum as the train running along a single line. The numerical model and calculation results presented in this paper can provide a theoretical method and evaluation basis for the study of train-bridge coupling vibration of multi-line subway viaduct.

Keywords metro train-bridge coupling system; numerical simulation; multi-line subway viaduct; moving in opposite direction; dynamic response

Axial Force Analysis of Flexible Cable Supported Photovoltaic Under Wind Load

MA Wenyong[1,2], *CHAI Xiaobing*[1], *GAO Fei*[3], *MA Chengcheng*[1], *WANG Caiyu*[1]
(1. Civil Engineering College, Shijiazhuang Tiedao University Shijiazhuang, 050043, China)
(2. Wind Engineering and Wind Energy Utilization Engineering Technology Innovation Center Shijiazhuang, 050043, China)
(3. Hebei Kunneng Electic Power Engineering Consulting Co., Ltd. Shijiazhuang, 053700, China)

Abstract To analyze the influence of wind load on the axial cable force in the flexible cable supported photovoltaic (PV), wind loads on PV modules at different wind directions, inclinations and spacing ratios are obtained through rigid model wind tunnel test. Three models are established and the axial cable forces under different conditions are calculated. The results show that the wind load on PV module varies with the position, and the wind load in the middle range is stronger than in others. The axial force on the cable is larger when the wind load is exerted as a concentrated load. The variation of the forces on support system with different inclination is also inconsistent with the layout (spacing ratio). Based on the analysis results, the present results suggest using a small spacing ratio and a large span, and the spacing ratio should be within 0.1. The wind load on the photovoltaic panel can be treated as a concentrated force to calculate the cable force. Meanwhile, the axial cable force caused by wind load can be estimated by the proposed ratio of wind load to axial cable force.

Keywords flexible cable supported photovoltaic; wind tunnel test; space ratio; axial cable force; ratio of wind load to cable force

Multi-source Identification Method Based on Cross-Spectral Matrix Function

WANG Yue[1,4], *YANG Chao*[1], *WANG Yansong*[1], *HU Dingyu*[2], *GU Rubin*[3]
(1. School of Mechanical and Automotive Engineering, Shanghai University of Engineering Science Shanghai, 201620, China)
(2. School of Urban Railway Transportation, Shanghai University of Engineering Science Shanghai, 201620, China)
(3. The 32128 Troops of the Chinese People's Liberation Army Jinan, 250000, China)
(4. Shanghai Yangpu Vocational and Technical School Shanghai, 200093, China)

Abstract In order to solve the aliasing problem in multi-source identification, a high-resolution deconvolution algorithm based on cross-spectral matrix function is proposed. Firstly, the algorithm decomposes the cross-spectral matrix associated with each peak source into eigenvalues and constructs a matrix function. Secondly, the matrix function is used to update the cross-spectral matrix function and output power in the process of deconvolution iteration. Finally, the distribution images of multiple sound sources are obtained by superimposing each clean beam and residual power spectrum. Simulations and experiments show that the main lobe of the output beam of the algorithm is narrow and the side lobe is low. This algorithm can not only effectively improve the dynamic range of the traditional deconvolution algorithm, but also achieve high-resolution identification of multiple sound sources.

Keywords acoustic source localization; beamforming; eigenvalue decomposition; deconvolution

In-situ Test and Numerical Simulation of Characteristics of Vibration Source of Metro Trains Arriving at or Leaving Station

WU Yubin[1], *SONG Ruixiang*[1], *JIANG Nan*[2], *WU Ya'nan*[1]
(1. Institute of Urban Safety and Environmental Science, Beijing Academy of Science and Technology Beijing, 100054, China)
(2. Beijing Municipal Institute of Environmental Protection Beijing, 100037, China)

Abstract In order to analyze the characteristics of vibration source of metro trains arriving at or leaving sta-

tion, a subway station is taken as the research object. The vibration acceleration of rail and station wall during metro train arriving at or leaving station is tested in situ.Results show that the vibration acceleration level of rail and station sidewall gradually decreases from the entrance end to the exit end of the station when the train enters. In addition, the difference of average vibration acceleration level of the side walls is about 20 dB. On the contrary, the vibration at the exit end is greater than that at the entrance end when the train leaves the station. The influence of metro train arriving and leaving the station on the frequency characteristics of rail and side wall acceleration is not obvious, and the acceleration frequency of station wall is mainly concentrated in 30～60 Hz. Based on the measured data, the variation formulas of vibration intensity are obtained by fitting, and the wheel-rail force load model and its application method are established considering the influence of vibration source intensity change caused by train arriving at or leaving station. This method has good accuracy in frequency domain and acceleration level, and the calculation error of acceleration level of the station sidewall can be controlled within 6%.

Keywords metro; vibration; in-situ test; numerical simulation; wheel-rail force

Failure-Diagnosis Approaches of VMD-MMPE-Based Rolling Elements and Cages in Rolling-Mill Bearings

JI Jiang[1,2,3], *ZHAO Chen*[3], *WANG Yongqin*[1]

(1. College of Mechanical Engineering, Chongqing University Chongqing, 400030, China)

(2. China National Heavy Machinery Research Institute Co., Ltd. Xi'an, 710032, China)

(3. National Cold Rolling Strip Equipment and Process Engineering Technology Research Center, Yanshan University Qinhuangdao, 066004, China)

Abstract Concerning the poor working conditions existing in rolling mill bearings, there have many problems, such as larger signal-noise interference, difficult identification, easy to damage cages and rolling elements, as well as higher diagnosis-speed requirements. This paper proposes the two feasible failure diagnosis approaches, namely particle swarm optimization - variational mode decomposition (PSO-VMD) and multivariate multiscale permutation entropy (MMPE). And with combination of particle swarm optimization - support vector machine (PSO-SVM), it successfully realizes identifications for multiple failures and corresponding classifications. The bearing vibration signal is processed by VMD into several intrinsic mode functions (IMF), and the optimal component envelope is selected for analysis. For the mill bearing vertical horizontal axial vibration difference, subject to large radial force and axial force characteristics, using MMPE to consider the four components of the three-dimensional vibration signal of the MMPE value and time domain indicators to form a feature vector. Finally, based on the model of PSO-SVM, it further verifies these methods in effectiveness. And through a series of comparisons with the achieved calculations and experimental results with ensemble empirical mode decomposition (EEMD) and local mean decomposition (LMD), it indicates that VMD-MMPE can better optimize model-inputting work, as well as enhance corresponding diagnostic accuracies and speeds. Finally, it realized effective diagnoses upon failures with different damage degrees in different and same parts of bearing cages and rolling elements, achieving important engineering significance.

Keywords rolling mill bear; variational mode decomposition (VMD); envelope spectrum; multivariate multiscale permutation entropy(MMPE); particle swarm optimization - support vector machine(PSO-SVM); fault diagnosis method

Bearing Fault Diagnosis Based on Generative Adversarial Nets Optimized by Evolutionary Conditions

LI Ke[1], *HE Shaojie*[1], *SU Lei*[1], *GU Jiefei*[1], *SU Wensheng*[2], *LU Lixin*[1]
(1. Jiangsu Key Laboratory of Advanced Food Manufacturing Equipment & Technology, Jiangnan University Wuxi, 214122, China)
(2. Jiangsu Province Special Equipment Safety Supervision Inspection Institute Branch of Wuxi Wuxi, 214071, China)

Abstract Aimed at the problem of unbalanced fault samples in rolling bearing fault diagnosis, a fault diagnosis method based on conditional generative adversarial nets optimized by evolutionary algorithm (ECGAN) is proposed. Firstly, the generator in conditional generative adversarial nets is optimized by evolutionary algorithm to generate new samples similar to the original sample distribution under different loss functions so as to expand the data set. Then, the generated sample and the original sample are input to the discriminator to extract the valid data features of the sample and judge the authenticity and category of the input sample. Finally, the generator and discriminator are optimized by counter learning mechanism to improve the fault recognition ability of the nets. The experimental results show that the ECGAN method has better performance in fault diagnosis in the case of unbalanced sample data types.

Keyword fault diagnosis; imbalanced classification; generative adversarial nets; evolutionary algorithm

Application of Improved Dispersion Entropy to Fault Detection of Axle-Box Bearing in Train

LI Yongjian[1], *SONG Hao*[1], *LI Peng*[1], *MIAO Bingrong*[2], *XIONG Qing*[3]
(1. School of Rail Transportation, Wuyi University Jiangmen, 529020, China)
(2. State Key Laboratory of Traction Power, Southwest Jiaotong University Chengdu, 610031, China)
(3. School of Intelligent Manufacturing and Automobile, Chengdu Vocational & Technical College of Industry Chengdu, 610218, China)

Abstract Aiming at the problem of early damage detection of axle box bearings, a diagnosis model based on improved multiscale dispersion entropy (IMDE) and support vector machine is proposed to effectively identify the health state of bearings by extracting key information from vibration signals. This method mainly considers the shortcomings of traditional multi-scale dispersion entropy (MDE), such as the increase of entropy standard deviation, the confusion of distribution and the obvious fluctuation caused by the problem of data point coincidence and the increase of coarse-graining scale. The algorithm is improved by optimizing the coarse-graining procedure and the dispersion entropy. Then, a practical example is given to verify the vibration data of high-speed train axle box bearing under different operating conditions by experiments. The results show that the standard deviation of IMDE is smaller and the robustness is better than MDE, and the classification results of support vector machine show that IMDE has higher diagnosis accuracy.

Keywords vehicle engineering; axle box bearing; dispersion entropy; feature extraction; fault diagnosis

Full Vector Autogram Based Fault Diagnosis Method for Rolling Bearing

ZHANG Liurun, *ZHENG Jinde*, *PAN Haiyang*, *TONG Jinyu*
(School of Mechanical Engineering, Anhui University of Technology Maanshan, 243032, China)

Abstract In this paper, a rolling bearing fault diagnosis method based on full vector spectrum and Autogram is

proposed to solve the problems of low signal-to-noise ratio and the incompleteness and inaccuracy of single channel signal of rolling bearing. Firstly, the Autogram algorithm is used to obtain the optimal frequency band position in the signal, and the signal is reconstructed according to the selected frequency band to improve the signal-to-noise ratio. Secondly, The full vector spectrum technology is used to fuse the reconstructed signals to ensure the comprehensiveness of fault information. Finally, according to the fault characteristics in the full vector envelope spectrum, the fault diagnosis results are obtained. The proposed method is compared with the fast spectral kurtosis and the existing methods by simulation and experimental data of rolling bearing analysis. Tested results show that the proposed fault diagnosis method can effectively extract the fault feature frequency of rolling bearing and improve the accuracy of fault diagnosis.

Keywords Autogram; fast spectral kurtogram; full vector spectrum; rolling bearing; fault diagnosis

Bandgap Properties of Star-Shaped Periodic Grid Structure with Negative Poisson′s Ratios

WANG Jie[1,2], *CHEN Guoping*[2,3], *HE Huan*[2,3], *PAN Yong*[1], *LIU Siyu*[1]

(1. Shanghai Electro-Mechanical Engineering Institute Shanghai, 201109, China)

(2. State Key Laboratory of Mechanics and Control of Mechanical Structures, Nanjing University of Aeronautics and Astronautics Nanjing, 210016, China)

(3. Institute of Vibration Engineering Research, Nanjing University of Aeronautics and Astronautics Nanjing, 210016, China)

Abstract Based on the band structure theory of phononic crystals, combined with the elastic wave equation and the Bloch theorem, the dynamic equation of the unit cell is established. The band gap of star-shaped periodic grid structure with negative Poisson′s ratio is studied, including in-plane longitudinal vibration and out-of-plane bending vibration. It is found that the structure has rich band gap characteristics, and the lower frequency band gap is stable and wide. Band gaps of the two vibration modes are compared, and the influence of geometric parameters, such as the concave angle and slenderness ratio, on the equivalent elastic parameters and band gap is studied. It also analyses the vibration modes of the unit cell at the gap frequency. Results show that there is a complete band gap in which two vibrations are both suppressed. Concave angle and geometric parameters of the oblique beam are keys to the low-order band gap. The appearance of the rotating resonance mode leads to the lowest band gap. Band gap characteristics of the star-shaped periodic grid structure make it potentially valuable in engineering vibration and noise reduction.

Keywords star-shaped structure; periodic structure; negative Poisson′s ratios; band gaps

Damage Detection of Transmission Tower Based on Stochastic Subspace and Statistic Model

CAO Meigen[1], *YANG Tingting*[2,3], *WANG Yu*[4], *ZHENG Chong*[4], *ZHOU Wensong*[2,3]

(1. School of Civil Engineering, North China University of Technology Beijing, 100144, China)

(2. Key Lab of Structures Dynamic Behavior and Control of the Ministry of Education, Harbin Institute of Technology Harbin, 150090, China)

(3. Key Lab of Smart Prevention and Mitigation of Civil Engineering Disasters, Ministry of Industry and Information Technology, Harbin Institute of Technology Harbin, 150090, China)

(4. Wenzhou Power Supply Company of State Grid Wenzhou, 325000, China)

Abstract Aiming at transmission tower structure, a damage detection method based on statistical model combined stochastic subspace identification algorithm is given, where vibration responses of transmission tower are

used to obtain statistical features and construct highly sensitive damage index in order to diagnosis damage of local components. Firstly, transient dynamic response signals are collected. Secondly, modal parameters are identified by stochastic subspace identification algorithm, nominal modal parameters are built accordingly and the residual vector is defined, which is related to the structural parameters variation. Finally, the sensitivity of the residual to structural parameters is calculated, and then the χ^2 statistic value of the residual sensitivity is constructed as the damage detection index. Through numerical simulation and field test, a full-scale transmission tower Is analyzed, the results show that the proposed method can effectively identify local components damage of transmission tower, such as bolt loosening and structural member failure.

Keywords transmission tower; structural vibration; stochastic subspace algorithm; statistic model; damage detection

Design and Strength Analysis of Sensor Installation Structure for Rail Vehicle Axle Box

JIANG Wei, *PENG Lele*, *ZHENG Shubin*, *CHEN Xieqi*, *CHAI Xiaodong*
(School of Urban Rail Transit, Shanghai University of Engineering and Technology Shanghai, 201620, China)

Abstract A sensor installation structure for the axle box of Shanghai Metro Alstom vehicle is designed to accomplish this goal. Through the structure and force analysis of the axle box, the axle box load and constraint conditions are determined. A data collection test is carried out to obtain the main frequency characteristics of the axle box vibration and the acceleration power spectral density. By using ANSYS Workbench and nCode finite element analysis software, the impact strength, modal and fatigue life of the installation structure are analyzed. The results show that the maximum equivalent stress of the installation structure is 121 MPa, which is less than the yield stress of the material. The safety factor is higher than 1.5 times. The first 6-order natural frequency of the structure is different from the main frequency of the axle box vibration, which ensures the stability of the structure. The cumulative damage of the vehicle's 3.6 million kilometers mileage is 1.76×10^{-3}, which is less than the damage threshold and meets the requirements of Vehicle quality. After 6 months vehicle operation test, damages like cracks and deformation is not detected on the sensor installation structure, and the reliable installation of the axle box sensor has been realized. Furthermore, the design and analysis method and engineering practical experience for the sensor installation of vehicle-rail safety monitoring can be used as a reference for related tasks.

Keywords rail vehicle; axle box sensor installation; axle box vibration characteristics; impact strength analysis; modal analysis; fatigue strength analysis

Fault Diagnosis and Optimization of Low Frequency Booming Noise for Electric Vehicle

CHEN Jiangyan[1,2], *HE Yansong*[1], *CHEN Yuanzheng*[2]
(1. School of Automotive Engineering, Chongqing University Chongqing, 400030, China)
(2. Chongqing Chaoli Hi-tech Co., Ltd. Chongqing, 401122, China)

Abstract Diagnosis and troubleshooting are proceeded for the low-frequency booming of an electric car. The noise and vibration of the vehicle and its parts are tested. The fault car and parts are analyzed based on order analysis, transfer path analysis, numerical simulation and other methods, and it is confirmed that the booming noise is generated through the process in which the first order vibration of the compressor is transmitted to the body through the mounting bracket to cause the resonance of the thin-wall sheet metal structure. According to the

noise and vibration control idea of source-path-response, analyzing one by one, the transfer path is confirmed to be the optimal improvement direction based on the engineering needs. Two technical schemes to increase the vibration isolation of the mounting bracket are proposed, and the effectiveness is verified on the vehicle. The research shows that the improvement of the transfer path can effectively reduce the booming noise caused by the vibration of the parts, and the total noise can be reduced by 11.9 dB(A), which provides a new idea for solving similar problems.

Keywords electric vehicle; compressor; booming noise; vibration and noise testing; transfer path analysis

Stress Severity Factor Method for Vibration Fatigue Life Analysis of Joints

HUA Yichang[1], *YAO Weixing*[1,2], *HUANG Jie*[1]

(1. State Key Laboratory of Mechanics and Control of Mechanical Structures, Nanjing University of Aeronautics and Astronautics Nanjing, 210016, China)

(2. Key Laboratory of Fundamental Science for National Defense-Advanced Design Technology of Flight Vehicle, Nanjing University of Aeronautics and Astronautics Nanjing, 210016, China)

Abstract A stress severity factor method for vibration fatigue life analysis of joints is proposed for the problems of stress concentration and contact nonlinearity, which is based on stress severity factor (SSF) method of quasi-static fatigue analysis for stress concentration and contact. The method can be extended to random vibration. An equivalent SSF model is used to calculate the stress response. An example shows that the calculation errors of vibration fatigue life under two excitation spectrums are 27.3% and 30.7% respectively. It indicates that the SSF method is fast and accurate, and meets the requirements of rapid estimation of vibration fatigue life of joints in engineering.

Keywords joints; vibration fatigue; stress severity factor(SSF) method; life estimation

Diagnosis of Slight Inter-turn Short-Circuit Fault of Synchronous Condenser Based on DST

ZHANG Yuliang[1,3], *MA Hongzhong*[1], *JIANG Mengyao*[1], *WEI Chao*[2], *LIN Yuandi*[2]

(1. College of Energy and Electrical Engineering, Hohai University Nanjing, 211100, China)

(2. State Grid Jiangsu Electric Power Co., Ltd. Research Institute Nanjing, 211103, China)

(3. Xuzhou Heavy Machinery Co., Ltd. Xuzhou, 221000, China)

Abstract Inter-turn short-circuit fault of rotor winding is a common fault of synchronous condenser, and once it appears, it will directly affect the reactive power output of the synchronous condenser in the system. Since the synchronous condenser often needs to adjust the reactive power in the process of operation, it is difficult to accurately diagnose the fault with only a single characteristic quantity, so it is easy to misjudge. In this paper, a diagnosis method based on DS evidence theory (DST) for slight inter-turn short-circuit fault of synchronous condenser is presented. In the diagnosis, the fault probability under the single feature quantity is firstly calculated by random forest, and then the results of the two are synthetically diagnosed by the combined rule of DST. Finally, it is verified by experiment. The experimental results show that the accuracy of the method is higher than that of the single feature, and it can effectively improve the identification accuracy of the slight inter-turn short-circuit fault of the synchronous condenser.

Keywords synchronous condenser; inter-turn short-circuit fault of the rotor; vibration analysis; random forest; DS evidence theory(DST); fault diagnosis

Fault Diagnosis of Vehicle On-Board Equipment Based on DBN-HD

WEI Wei[1], *ZHAO Xiaoqiang*[2,3], *FAN Liangliang*[4]

(1. School of New Energy and Power Engineering, Lanzhou Jiaotong University Lanzhou, 730070, China)

(2. College of Electrical and Information Engineering, Lanzhou University of Technology Lanzhou, 730050, China)

(3. National Experimental Teaching Center of Electrical and Control Engineering, Lanzhou University of Technology Lanzhou, 730050, China)

(4. Lanzhou Telecommunication and Signal Depot, China Railway Lanzhou Bureau Group Co., Ltd. Lanzhou, 730050, China)

Abstract The fault diagnosis of automatic train protection (ATP) vehicle on-board equipment mainly depends on experience of maintenance, which is inefficiency. Vehicle fault diagnosis model of deep belief network-Hamming distance (DBN-HD) is proposed. Firstly, the abstract features of vehicle fault data are extracted by using DBN unsupervised to obtain the low-dimensional representation of original data and output through the classifier at the top layer. Secondly, the HD between the actual output and the expected output is compared, and HD is used as the error to fine-tune the DBN weight from top to bottom by adopting back propagation (BP) algorithm simultaneously. Finally, the effect of model parameters on the performance is analyzed and verified by using the vehicle fault data of the telecommunication and signal depot of some group company. Compared with support vector machine (SVM), back propagation neural networks (BPNN) and DBN, the proposed model has higher accuracy and operation efficiency, and is suitable for fault diagnosis of actual vehicle equipment.

Keywords vehicle on-board equipment; fault diagnosis; deep belief network; Hamming distance

Analysis and Test on Permissible Residual Unbalance of Rotors

GE Yuzhu[1], *LEI Xuemei*[1], *ZHANG Yuechun*[2], *FANG Zhixiang*[1], *LU Zhang*[1]

(1. Hunan Fine High Intelligent Equipment Co., Ltd. Zhuzhou, 412000, China)

(2. Hunan Hangxiang Gas Turbine Co., Ltd. Zhuzhou, 412000, China)

Abstract Focus on the balance of rotors, international widely used methods of permissible residual unbalance is analyzed, the principles, starting points and development history of various standards and related formulas is discussed, the meanings of physical quantities used in different equations is specified, and suggestions and matters needing attention on using these equations is proposed. Forces due to permissible residual unbalance and its ratio in the static journal loads from different methods are compared. The tests verifies the influence of the permissible residual unbalance on the vibration and temperature of the high-speed rotor machine. For commonly used balance quality grades, considering the sensitivity of conventional balance machines, the permissible residual unbalance specified by American Petroleum Institute (API) is the smallest, and the impact on bearing life is also the smallest. To determine appropriate permissible residual unbalance, it should consider the sensitivity of dynamic balancing machine in practical engineering. The permissible residual unbalance should be allocated to correction planes according to corresponding criteria. Special attention should be paid that the meanings of the same physical quantity used in equations on permissible residual unbalance are different, each method has strong industry characteristics and era characteristics. Among them API is with more application value as takes into account the sensitivity level of dynamic balancing machines, and is more technologically advanced, economical and operability.

Keywords rotors; permissible residual unbalance; balance quality grades; allocation; forces due to unbalance; sensitivity of balance machine

Simultaneous Optimization of the Structural and Operating Parameters for Front Girder System of Quayside Container Crane

QIN Xianrong, *ZHAN Pengming*, *WANG Yulong*, *HAO Ruolan*, *SUN Yuantao*, *ZHANG Qing*
(School of Mechanical Engineering, Tongji University Shanghai, 200092, China)

Abstract The front girder system of quayside container crane (QCC) is optimized considering the structural and operating parameters simultaneously. First, the simplified mechanical model of the front girder system is established and its validity is proved by comparing the first three modal results of the finite element model of the whole machine and the simplified model. Secondly, in order to improve the computational efficiency of the optimization process, the dynamics equation of the simplified model is gained by combing the assumed modal method and Lagrange equation. Then, taking the maximum load swing angle of the simplified model calculated by the Runge-Kutta method, the maximum deflection at the midpoint of the front girder and the total running time of the trolley as the optimization objective functions, the multi-objective genetic algorithm is used to calculate the structural and trolley operation parameters of the front girders of the QCC, and the Pareto optimal set is obtained. Finally, according to the specific requirements of the system performance, a reasonable solution is chosen from the set, which will guide the structural design of the front bridge girder system and the setting of the trolley operating parameters, and provide a new idea for anti-swinging of the QCC.

Keywords optimal design; quayside container crane; structural optimization; operating parameters; genetic algorithm

Low-Cyclic Loading Experimental Study on Timber Buckling-Restrained Braces

LU Weidong[1,2], *CAI Yupeng*[1], *LIU Pengyue*[1], *ZHANG Feng*[1]
(1. College of Civil Engineering, Nanjing Tech University Nanjing, 211816, China)
(2. Architectural Design and Research Institute, Nanjing Tech University Nanjing, 210009, China)

Abstract In order to improve the seismic performance of glued-laminated timber frames, the low-cycle loading tests of four timber buckling-restrained braces (TBRB) are carried out. The mechanical properties, failure modes, hysteresis curves, ductility, and energy dissipation capacity of timber buckling-restrained braces are analyzed. The test results showed that the failure modes of the specimens include the tensile failure of steel core, local buckling of steel core and local compression failure of timber, multi-wave buckling of steel core and crack of timber. The hysteretic curve of each specimen has a typical fusiform shape, which means TBRB have good energy dissipation capacity and large initial stiffness. The ductility and energy dissipation capacity of TBRB strengthened with steel plates and end-reinforced hoop are significantly improved, compared to the TBRB without being strengthened. The test results show that TBRB strengthened with steel core plates and end-reinforced hoop can achieve better seismic performance, which reveals the application prospect in seismic design of glued-laminated timber frames.

Keywords glued-laminated timber frames; timber buckling-restrained braces (TBRB); steel plates; seismic performance; low-cycle loading tests

Influence of Porosity and Snow Form on Protective Effect of Snow Fence

LIU Qingkuan[1,2,3], *LI Haifei*[3], *JIA Yaya*[1,2,3], *SUN Yuanchun*[4], *GAO Ling*[5]

(1. State Key Laboratory of Mechanical Behavior and System Safety of Traffic Engineering Structures, Shijiazhuang Tiedao University Shijiazhuang, 050043, China)

(2. Innovation Center for Wind Engineering and Wind Energy Technology of Hebei Province Shijiazhuang, 050043, China)

(3. School of Civil Engineering, Shijiazhuang Tiedao University Shijiazhuang, 050043, China)

(4. China Railway Design Corporation Tianjin, 300251, China)

(5. Hebei Provincial Communications Planning and Design Institute Shijiazhuang, 050011, China)

Abstract Base on the engineering snow-prevention measures of the drifting snow disaster along railway and highway, the method of combining numerical simulation and field observation is employed to study the influence characteristics of the porosity and snow form at different stages on the flow field around the snow fence, analyze the formation mechanism of snow cover at different stages, and obtain the evolution law of snow cover around the snow fence. The results show that: with the increase of the snow-fence porosity, the low speed zone and vortex range of the leeward side decreases gradually, which cause the snow accumulation velocity becomes slower. Furthermore, the first stacking position of snow is all in the range of $5H$~$9H$ on the leeward of the snow fence for different porosities, and gradually extends to both sides of the accumulated snow. The bottom gap of snow-fence makes the air flow accelerate at the bottom of the snow fence and snow particles are not easy to deposit, which effectively prolongs the time that the snow fence is buried. The range of the snow particles position is $-2.5H$~$18H$ on both sides of the snow fence, and the growth rate of snow slows down gradually with the continuous increase of snow thickness.

Keywords snow fence; drifting snow disaster; field measurement; snow distribution; porosity

Noise Reduction Method of Pipeline Leakage Signal Based on Variational Mode Decomposition

LIU Boxiang[1], *ZHANG Yuanmin*[2], *JIANG Zhu*[1]

(1. School of Energy and Power Engineering, Xihua University Chengdu, 610039, China)

(2. China Unicom (Sichuan) Industrial Internet Co., Ltd. Chengdu, 637000, China)

Abstract The noise reduction of the pipeline leak signal is the key to precisely locate the leakage point. However, the signal has non-stationary and non-linear characteristics, and the traditional method has a limited denoising effect on this type of signal. In order to effectively eliminate noise and improve the accuracy of leak location, an adaptive noise reduction method based on variational mode decomposition (VMD) is proposed. Initially, the effective intrinsic mode function (IMF) is screened by the correlation coefficient to realize the signal reconstruction. Then, according to the minimum value of the information entropy of the reconstructed signal, the optimal number of decomposition layers and the optimal denoising signal of VMD are obtained; Finally, the leakage location is realized by the theory of negative pressure wave. A pipeline leakage experiment system is built to verify the presented method. The results demonstrate that the developed method can effectively suppress noise, retain the waveform characteristics of the signal, and identify a distinct inflexion of the negative pressure wave. The minimum relative error of positioning is 0.9% and the maximum is 3.75%. Compared with the traditional method, the presented method has higher positioning precision and more stable results.

Keywords negative pressure wave; leak location; adaptive noise reduction; variational mode decomposition; information entropy; correlation coefficient

YMC®

专业化的设计与制造

保证每只产品的可靠性能

扬州英迈克测控技术有限公司

YMC PIEZOTRONICS INC

YMC压电式加速度计系列

- ◇ 低频高灵敏度：低至0.1 Hz
- ◇ 高冲击：达10万G
- ◇ 小型化：轻至1.5克
- ◇ 多轴向：三轴、多轴向
- ◇ 特种：防水型、高温型

中国扬州市祥云路47号
电话:0514-87960802
邮箱: sales@chinayme.com

更多信息请访问：WWW.chinaymc.com

dasp

北京东方振动和噪声技术研究所 www.coinv.com

上千用户正在使用的

模态试验之解决方案

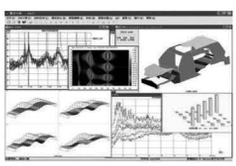
专业 —— 先进 —— 易用

灵活：支持各种试验方法，应对各种复杂现场

- 试验类型：**EMA**，**OMA**，**ODS**
- 激励响应：**MIMO**，**SIMO**，**MISO**，**VTB**，应变模态
- 更多内容：**GVT**，**TPA/OTPA**，动力修改，刚体参数测量等

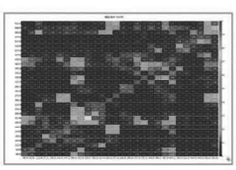
精确：高精度的原始测量数据是关键

- 高精度 **ADC**：**24bit/120dB**，双核 **24bit/160dB**
- 集中式测量：**128κHz X 1000 Channels**
- 分布式测量：**GPS/北斗/LXI** 同步,**WIFI/3G/**以太网



先进：内含各种现代拟合算法和创新算法

- 时域法：**PolyIIR**，**SSI**，**ERA**，**Prony**
- 频域法：**PolyLSCF**，**EFDD**，纯模态算法，**PPM**，**PZM**
- 更多领先：连续激励精确 **FRF**，无附加质量声测模态
- 一锤定音：一次激励得到相干函数，试验效率极大提高



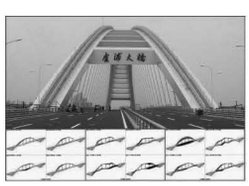
可靠：复杂结构的模态结果必须经过多方校验

- 相关校验：**MAC/pwMAC**，**MP**，**MOV**，**MPC**，**MII**
- 对比校验：多种拟合算法校核、实测与综合 **FRF** 对比
- 仿真校验：导入有限元 **FEM** 结果进行 **CrossMAC**

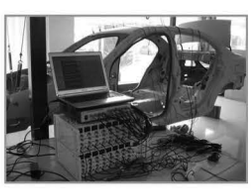
智能：自动化模态分析

- 基于 **MII** 和参数优化理论的自动化分析
- 一键得出专家级模态分析结果
- 在线模态监测、时变模态分析都已成为现实

- **1988** 成功完成 小型火箭激励 钱塘江大桥
- **1991** 国际先进 VTB 变时基技术 申请专利
- **1996** 成功完成 乌海黄河桥 锤击法试验成功
- **2002** OMA 6 种先进算法 全面推广应用
- **2010** PolyIIR 超清晰稳定图算法 国际发表
- **2012** 成功完成 航天器点火 变温模态成功
- **2015** 2300 吨 火箭发射平台 EMA 模态成功



百余座桥梁及大型土木结构



汽车车身及部件

航天发射平台

分布式/云智慧测量设备

集中式高性能测量设备

详细信息请联系东方所 **www.coinv.com** **dasp@coinv.com** **010-62989889** **24** 小时技术支持 **13910014842**