Research Status of Key Technologies and Equipment for Mini/Micro LED Mass Transfer

TANG Hui[1], *LIAO Zhishen*[1], *WEI Yuzhang*[1], *LIN Zhihang*[1], *DONG Zhiqiang*[2], *ZHANG Xiaohui*[3,4]

(1. School of Mechanical and Electrical Engineering, Guangdong University of Technology Guangzhou, 510006, China)

(2. Guangzhou Nadon Semiconductor Equipment Co.,Ltd. Guangzhou, 510006, China)

(3. School of Materials Science and Engineering, South China University of Technology Guangzhou, 510006, China)

(4. Jihua Laboratory Foshan, 528255, China)

Abstract Mini/micro light emitting diode display technology (Mini/Micro LED) is a self-luminous display technology based on micro LED chips. Compared with liquid crystal display technology (LCD) and organic light emitting diode display technology (OLED), it has significant performance advantages and is regarded as the development trend of next-generation display technology. However, due to limitations in mass transfer technology and equipment, Mini/Micro LED display equipment has not yet achieved large-scale mass production. To address this issue, firstly three main process methods are summarized based on the different working principles of existing Mini/Micro LED mass transfer process methods, namely contact micro-transfer technology, non-contact laser transfer technology and self-assembly transfer technology. Secondly, the technology and equipment involved in the existing Mini/Micro LED mass transfer process methods are investigated, and the common key technologies are summarized, namely high-speed and high-precision alignment and visual inspection. Then, in response to the above key technical challenges, the authors conduct systematic and in-depth research on the integrated development of several key technologies and typical equipment in the new Mini/Micro LED display field. Finally, the existing problems and development directions in achieving large-scale mass production of Mini/Micro LED are discussed.

Keywords Mini/micro light emitting diode (Mini/Micro LED); mass transfer; display semiconductor equipment; precision alignment; vibration suppression

Applicability of Leaky Surface Wave IMF_1 Energy to Identify Ballastless Track Void

MA Jiapei[1,2], *YUAN Shengzhe*[1,2,3], *XIAO Junhua*[1,2], *LI Hang*[1,2], *PAN Yue*[1,2], *SU Zhipeng*[1,2]

(1. The Key Laboratory of Road and Traffic Engineering, Ministry of Education, Tongji University Shanghai, 201804, China)

(2. Shanghai Key Laboratory of Rail Infrastructure Durability and System Safety Shanghai, 201804, China)

(3. Guangxi Communications Design Group Co., Ltd. Nanning, 530029, China)

Abstract To study the applicability of the leaky surface wave method for identifying the interstratified void of high-speed railway ballastless track, the authors establish the characteristic index of the void, through the full-scale model test of slab ballastless track with the interstratified void. Then, the coupled finite element model of air ballastless track is established to analyze the distribution characteristics of impact response sound field under different working conditions. The Hilbert Huang transform is further performed on the leaky surface wave signal, and the high-frequency characteristic signal is retained to the first order intrinsic mode function (IMF_1). Further, the low-frequency interference signal is decomposed to the higher-order eigenmode function, and the interlayer void identification method is proposed based on IMF_1 energy. The results show that the energy distribution of leaky surface wave IMF_1 presents a positive correlation trend, with the increase of void length and the distance from void to load impact point. In addition, IMF_1 energy is sensitive to cement asphalt (CA) mortar layer void 0.2~0.5 m in China railway track system II (CRTSII) type ballastless track slab, and CA mortar layer

void identification based on the leaky surface wave has certain theoretical feasibility.

Keywords slab track; void identification; leaky surface wave; intrinsic mode function(IMF); IMF_1 energy

Vertical Bending Vibration Characteristics of Box Composite Cirder with Corrugated Steel Webs

ZHANG Zichen[1], *WANG Genhui*[2], *WANG Xing*[1], *JIN Xuejun*[2]
(1. School of Civil Engineering, Qinghai University Xining, 810016, China)
(2. School of Civil Engineering, Lanzhou Jiaotong University Lanzhou, 730070, China)

Abstract Considering the effects of shear deformation, shear lag warping stress self-equilibrium, moment of inertia and web accordion effect, two different shear lag angle difference functions are set up for the upper and lower wing plates and cantilever plates of composite box girder. The elastic governing differential equations are established based on the energy variational method, Hamilton principle, and natural boundary conditions of the structure, and the closed solutions of the corresponding generalized displacements are obtained. The reliability of the closed form solution is verified by the measured values of the model and the finite element analysis from ANSYS software. Finally, the influence of width span ratio on the vertical bending vibration characteristics of composite box girder is analyzed. The results show that compared with the shear lag effect, the shear deformation has a greater influence on the flexural stiffness of composite box girder, and the difference of the fourth natural frequency is 27.623%. The distribution characteristics of the dynamic stress amplitude at each point of the cross section in the middle span of the structure are similar to the static analysis results, and the influence of the load frequency on the dynamic shear lag coefficient of composite box girder is less than 3.52%. Moreover, the influence of shear lag effect on the dynamic stress amplitude of simply supported composite box girder flange increases with the augment of width span ratio, and the influence of warping stress self-equilibrium also increases. In addition, the contribution of warping stress self-equilibrium to the natural frequency of the structure is less than 5%, but the influence on the dynamic stress amplitude of flange can reach more than 9.4%.

Keywords box composite girder with corrugated steel webs; vibration characteristics; self-equilibrium condition; shear lag effect; energy variational method

Mechanical Fault Diagnosis of GIS Circuit Breakers Based on Voiceprint

LI Ke[1], *YAO Zhongyuan*[1], *WANG Xiao*[2], *GU Jiefei*[1], *SU Lei*[1], *XUE Zhigang*[3]
(1. Jiangsu Key Laboratory of Advanced Food Manufacturing Equipment and Technology, Jiangnan University Wuxi, 214122, China)
(2. Shanghai Rhythm Electronic Technology Co., Ltd. Shanghai, 201108, China)
(3. Jiangsu Province Special Equipment Safety Supervision Inspection Institute Branch of Wuxi Wuxi, 214071, China)

Abstract An effective method to diagnose the mechanical faults of gas insulated switchgear (GIS) circuit breakers is proposed to solve the problem, that the sound signals are easily interfered by strong background noise, and the feature extraction is difficult. Firstly, the original observation signals are collected by a multi-channel acoustic sensor array, the observation signals are separated into multi-dimensional source signals by independent component analysis (ICA), and the least fuzzy entropy component of the source signal is selected as the characteristic signal. Secondly, the multi-scale fuzzy entropy (MFE) of the characteristic signal is calculated to generate the voiceprint feature of the circuit breaker. Lastly, the extreme learning machine (ELM) algorithm is used to identify the fault. The experimental results show that the detection method based on acoustic signals provides a new solution for GIS circuit breaker mechanical fault diagnosis. The proposed algorithm can effec-

tively extract voiceprint features, and the fault diagnosis accuracy is significantly improved compared with traditional methods.

Keywords gas insulated switchgear (GIS) circuit breaker; mechanical fault diagnosis; voiceprint; independent component analysis; multi-scale fuzzy entropy; extreme learning machine

Dynamic Track Tension Control System Based on Fuzzy PID

CHEN Bing[1], *MA Kaixuan*[1], *LIU Yang*[1], *FENG Zhanzong*[2], *ZHAO Taoshuo*[2], *SUN Zhihui*[1]
(1. School of Mechanical Engineering, University of Science and Technology Beijing Beijing, 100083, China)
(2. China North Vehicle Research Institue Beijing, 100072, China)

Abstract Track tension is the main factor that affects the reliability of the track. Maintaining the stability of the track tension is conducive to improve the service life of the track, and meanwhile to enable the vehicle body to exert superior performance in off-road conditions. This paper establishes a theoretical estimation model of the track tension through the geometric relationship and force analyses of the free body diagrams among the supporting roller, road wheel, idler, and track tensioner. The comparison with the simulation results of multi-body dynamics verifies the rationality of the theoretical estimation model of track tension. On this basis, a track tension control system is designed in terms of fuzzy proportional-integral-derivative (PID) control. The tightness of the track can be adjusted by rotating the crank arm of the idler. The simulation results show that the control system can quickly and accurately achieve the expected track tension. Compared with the fixing method of idler, this control system effectively reduces the dynamic track tension of the crawler in the grounding section, and reduces the track tension while not increasing the risk of the track slipping off the wheel. Further, the vibration of the vehicle body and the impact load of the track on the supporting roller are effectively suppressed, and the reliability of the track vehicle is increased.

Keywords track tension; idler; mathematical model; fuzzy PID; RecurDyn+Matlab/Simulink co-simulation

Matching Design for Electrical Impedance of Ultrasonic Peen Forming Transducers Operated at High Voltages

SHI Lukai, *LU Xiaolong*, *LI Wuqin*, *QIAN Feng*, *CAO Da*, *LI Huafeng*
(State Key Laboratory of Mechanics and Control of Mechanical Structures, Nanjing University of Aeronautics and Astronautics Nanjing, 210016, China)

Abstract On the basis of the impedance variation under different voltages, an electrical matching design is presented to improve the performance of ultrasonic peen forming (UPF) transducers operated at high-voltage conditions. Firstly, the voltage, current and temporal phase difference are measured for UPF transducers under high driving voltages, and then the actual impedance characteristic curve is obtained. Secondly, inductor values for both parallel and serial matching circuit are calculated and testified at resonance frequency for the UPF transducer. Then, the inductance value is accurately tuned to achieve the ideal pure resistant characteristic with the largest active power. Finally, the matching design is coupled with self-made driving board to supply electrical powers for UPF transducer, and the peening performances before and after matching are compared by measuring the movement of impact pins. Experimental results reveal that the maximum displacement for impact pins increases from 2.7 mm to 4.9 mm after incorporating the serial matching circuit with 2.6 mH inductor, demonstrating the feasibility and effectiveness of the proposed matching method.

Keywords ultrasonic peen forming transducer; resonant frequency; impedance characteristics; matching circuit

A New Type of Pressure / Tensile Integrated Hopkinson Bar

WANG Fan, *CHEN Longyang*, *ZHAO Sihan*, *WU Qian*, *GUO Weiguo*
(School of Aeronautics, Northwestern Polytechnical University Xi'an, 710072, China)

Abstract Split Hopkinson bar equipment is an important method for measuring the dynamic properties of materials. In order to improve the efficiency and economic efficiency of the equipment, a kind of integrated Hopkinson bar device which can realize both material dynamic compression and tension is studied. By adding a Y-shaped front component, a pair of side bar and Y-shaped back component to the split Hopkinson pressure bar equipment, the compression wave generated by impact can be converted into a tensile wave which loads on samples. Using ABAQUS software, a numerical simulation is conducted to analyze the change of waveform which is influenced by geometric configuration of front and back components, including the size and distance of side bars. The results show that the bifurcation angle increase the front Y-shaped component and the decrease of the cross-section size aggravate waveform distortion. The section size has a negative exponential relationship with the distortion degree. When the length of the side bars section is greater than 10 mm, the distance between side bars has little effect on the waveform. The tensile wave amplitude is positively correlated with the flange thickness. Finally, it is determined that the bifurcation angle of the front component is 10°, the distance between side bars is 60 mm, and the flange thickness of the back component is 10 mm. Therefore, a kind of integrated Hopkinson bar device that applies to both compression and tensile is established, and the compression and tensile loading experiments of two samples are respectively carried out to verify the effectiveness and stability of this device.

Keywords Hopkinson bar; integration of compression and tension; dimension optimization; curved bar; dynamic performance

Evaluation of Winding Mechanical Condition Based on Broadband Energization Vibration Signals

ZHU Hao[1], *MA Hongzhong*[1], *LIU Baowen*[1], *YAN Jin*[1], *ZHANG Yuliang*[1], *XU Honghua*[2]
(1. College of Energy and Electrical Engineering, Hohai University Nanjing, 211100, China)
(2. Nanjing Power Supply Company of State Grid Jiangsu Electric Power Co., Ltd. Nanjing, 210019, China)

Abstract The winding mechanical state diagnosis method based on discrete frequency vibration signal cannot truly reflect the structural characteristics of the winding and has low sensitivity to early winding loosening fault. This paper presents a mechanical state detection method of transformer windings based on broadband vibration signals. Firstly, the axial vibration mechanism of the winding is studied when the transformer is energized without load. Based on the principle of least action, the dynamic equation of the dual-conductor vibration model is established. Then, the modal components containing the high frequency components under the fundamental frequency of winding and electromechanical coupling effect are obtained by variational modal decomposition (VMD) optimized by whale optimization algorithm (WOA). Finally, the sample entropy (SampEn) value and spectrum peak value of the signal are calculated, and the mechanical state of the transformer winding is detected according to the change of sample entropy and spectrum peak value. The results show that the parameter resonance of the winding appears with the change of its natural frequency, and the noise reduction effect of WOA-VMD algorithm is better than that of ordinary VMD algorithm. The winding mechanical state diagnosis method based on broadband vibration signal can effectively reflect winding loosening fault, which verifies the feasibility of transformer winding fault diagnosis based on broadband response.

Keywords power transformer; broadband vibration signal; transformer winding; whale optimization algorithm (WOA); variational modal decomposition (VMD); mechanical condition assessment

Optimization for Steering Wheel Vibration of a Commercial Vehicle at High Speed Cruise

LI Li, *JIANG Jianzhong*, *WANG Yue*, *YAO Jingjing*, *SUN Jiawei*
(BAIC Foton Motor Co., Ltd. Beijing, 102206, China)

Abstract Aiming at the severe vibration of the steering wheel in a medium-sized commercial vehicle under high-speed driving condition, this paper respectively studies the excitation source and transfer path from simulation and experimental analyses. Firstly, by using the order, modal and working deformation analysis methods, it is found that the vibration problem of the high-speed steering wheel is mainly caused by the coupling between the excitation frequency of the dynamic unbalance of the transmission shaft at high speed and the first-order vertical bending natural mode of the steering system. On the basis of this analysis, the improved optimization scheme is proposed and implemented from the aspects of system and excitation, so as to effectively control the vibration of the steering wheel at high speed. In addition, optimization and rectification process of this problem provides a reference for the design and development of vehicle steering system and the quality control of key components, which can effectively shorten the vehicle development cycle.

Keywords vibration of wheel; order analysis; coupling; dynamic unbalance; transfer path

Flow Noise Experimental Study on Circulating Water Pipeline System

LI Ning, *WANG Xianzhong*, *LIN Hongzhou*, *YU Min*
(School of Naval Architecture, Ocean and Energy Power Engineering, Wuhan University of Technology Wuhan, 430063, China)

Abstract In order to study the flow noise of the circulating water pipeline system and its control method, experiments of flow noise are carried out based on the self-built circulating water pipeline system. Tested environment is improved to ensure the rationality and reliability of the experimental data by measuring the background noise and improving the installation method of the hydrophone. And then, the measured noise results of the T-tube and curved tube are compared with the numerical results. Experimental results of the T-tube is in good agreement with the numerical results, while the experimental results of the curved tube is slightly different from the numerical results. Based on this experimental study on the noise reduction effect of the pipeline with guide vanes, the curved tube with guide vanes is better than that of the T-tube. The main reason is that the guide vane is set in the middle of the T-tube, which has a certain guiding effect. However, it will reduce the flow area to produce a greater flow velocity and affect the final noise reduction effect.

Keywords water pipeline system; background noise; hydrophone installation; noise validation; guide vane

Small Sample Bearing Fault Identification Method Using Novel Multi-scale Convolutional Neural Network

XING Ziyang, *ZHAO Rongzhen*, *WU Yaochun*, *HE Tianjin*
(School of Mechanical & Electronic Engineering, Lanzhou University of Technology Lanzhou, 730050, China)

Abstract The existing deep learning fault diagnosis methods are difficult to obtain high fault classification accuracy with fewer training samples. A novel multi-scale convolutional neural network (NMS-CNN) fault identification method is proposed. First, fast Fourier transform (FFT) on the original vibration signal of the rolling bearing is performed to obtain its frequency domain information. Secondly, it is transmitted into a multi-scale convolutional neural network to extract the multi-granularity information in the data and use instance normalization (IN) for feature standardization. Then, the attention mechanism is used to adaptively weight the multi-scale

features and further use convolution to extract deep abstract features. Finally, the softmax classifier is used to complete the fault identification task. After experimental verification, this method can complete the fault identification task excellently with fewer training samples. Moreover, its noise resistance and generalization are better than other mainstream intelligent fault identification algorithms.

Keywords fault identification; deep learning; multi-scale convolutional neural network; instance normalization; small sample

Uncertainty Quantification of Micro-contact Characteristics of Bolt Joint Surface

LI Ling, *LÜ Guohao*, *LIN Hong*, *WANG Jingjing*, *CAI Anjiang*
(School of Mechanical and Electrical Engineering, Xi′an University of Architecture and Technology Xi′an, 710055, China)

Abstract There are obvious uncertainties in the micro-contact characteristics of the bolt joint surface. Traditional models based on the deterministic theory are difficult to completely characterize the micro-contact characteristics of the joint surface. For this reason, a Monte Carlo method based on the uncertainty quantification method of the micro contact characteristics of the bolt joint surface is proposed. First, based on the fractal theory, the profile height of the asperity of the bonding surface with the same roughness is characterized, and the surface topography parameter range of the bonding surface is solved by the moment spectrum method. Then, using the central limit theorem, the surface topography parameter interval is changed to a Gaussian distribution function conforming to the profile height distribution of the asperity, which solves the reduction in confidence level caused by the accumulation of random sampling errors. Finally, the uncertainty of the surface topography parameters is embedded in the Monte-Carlo method, and the interval estimation of the contact characteristics of the bonding surface is obtained. Through comparative analysis, the influence of the contact gap on the contact characteristics is revealed when considering the uncertain factors. Studies have shown that the uncertainty of surface topography parameters has a significant impact on the change of the contact characteristics of the bolt joint surface, and causes the influence of uncertainty to accumulate. This method provides a theoretical basis and reference for accurately quantifying the uncertainty of the bolt joint surface.

Keywords bolt joint surface; uncertainty; contact characteristics; fractal theory; Monte-Carlo method

Experimental Study on Dynamic Characteristics of CRTSIII Vibration Reduction Slab Ballastless Track Applied in Station

CAI Xiaopei[1], *WANG Qihao*[1], *LIANG Yanke*[2], *LIU Mai*[1]
(1. School of Civil Engineering, Beijing Jiaotong University Beijing, 100044, China)
(2. China Railway Design Corporation Tianjin, 300142, China)

Abstract In order to study the vibration reduction characteristics of CRTSIII vibration reduction slab ballastless track at Xiong′an station of Beijing-Xiong′an intercity railway, three tests are carried out, including rubber material test, axle drop test and field driving test. From the multi-dimensional aspects of theoretical vibration reduction performance, internal vibration distribution law, transmission mechanism inside track, field vibration response of station, and according to rubber hardness, acceleration time-frequency characteristics, vibration insertion loss, station vibration level and other indicators, the mechanism and vibration control effect of CRTSIII vibration reduction slab ballastless track are studied. The results show that the average hardness of the rubber pad used for CRTSIII vibration reduction slab ballastless track is 48.5 at room temperature, and the vibration above 35.65 Hz can be theoretically controlled. When the vibration caused by axle drop is transmitted from top to bottom in the track structure, the high-frequency component decays rapidly. With the distance from the axle drop

point, the track vibration first decreases and then increases. Compared with common ballastless track, the vibration insertion loss for base plate of CRTSIII vibration reduction slab ballastless track is close to 10 dB. The CRTSIII vibration reduction slab ballastless track can effectively control the station vibration caused by train passing.

Keywords station vibration; vibration-reduction ballastless track; rubber hardness; wheel load drop test; on-situ operation test

Research on Dynamic Response of Top Soil on the High-Filled Slope of Cold Region Airport

LIU Guoguang[1,2,3], *PEI Leiyang*[1,4], *NIU Fujun*[2]

(1. College of Transportation Science and Engineering, Civil Aviation University of China Tianjin, 300300, China)

(2. State Key Laboratory of Frozen Soils Engineering, Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences Lanzhou, 730000, China)

(3. University of Chinese Academy of Sciences Beijing, 100039, China)

(4. School of Civil Engineering, Sun Yat-sen University Guangzhou, 510275, China)

Abstract In order to solve the safety issues of top soil on the airport high-filled slope in cold regions, parallel vibration model and fast Fourier transform (FFT) are introduced into the analysis on the dynamic behavior of frozen soil samples in temporal domain and frequency domain via the shaking-table experiment. By which, a novel dynamic stability analysis method is proposed by investigating the response frequency. The result shows that there is significant increase in the ratio of acceleration growth (R_a), frequency and the ratio of frequency growth (R_f) during thawing process. However, the variation trend of acceleration amplitude is not so obvious. With higher mass water contents, the thawing process is shorter, R_f is greater and response frequency is higher after completely thawed. Meanwhile, the acceleration amplification coefficient is less influenced by mass water contents. During the high-temperature freezing period, there is a mutation of R_f while R_a still remains unchanged. It indicates that the analysis on dynamic behavior of frozen soil samples is more sensitive in frequency domain compared with the temporal domain. The outcomes of shaking table experiment also prove the reliability of the proposed parallel vibration model of soil. It is helpful for the stability monitoring of high-filled slope in the cold regions.

Keywords geotechnical engineering; engineering in cold regions; high-filled slope; dynamic response characteristic; thawing event; shaking-table test

Semi-supervised Fault Diagnosis for Dual-rotor Bearing Based on Improved CNN and Kmeans

CUI Jinmiao[1], *HE Ya*[1,2], *FENG Kun*[1,2]

(1. Key Lab of Engine Health Monitoring-Control and Networking of Ministry of Eduation, Beijing University of Chemical Technology Beijing, 100029, China)

(2. Beijing Key Laboratory of High-end Mechanical Equipment Health Monitoring and Self-Recovery, Beijing University of Chemical Technology Beijing, 100029, China)

Abstract It is difficult for the convolution neural network (CNN) to train when some types of fault data are lacking in engineering, a semi-supervised fault diagnosis method of intershaft bearing is proposed based on improved CNN and Kmeans. Firstly, the autoregressive model (AR) is used to denoise the dual-rotor bearing signal and the signal spectrum is obtained by fast fourier transform as the input of CNN. Then, CNN is established based on the frequency domain function of Morlet wavelet basis. Combining with Softmax loss and weighted

inner-product minimization loss proposed in this paper, CNN is trained under the condition of few categories of training data. Finally, Kmeans clustering is used to analyze the linear output of CNN to determine the pseudo labels of unlabeled data. CNN is trained iteratively with the idea of self-training in Semi-supervised learning to update the pseudo labels, and then the normal, known and unknown faults of the dual-rotor bearing are divided based on the pseudo labels. The method is verified by the data of dual-rotor bearing fault simulation test bed. With the 100% diagnostic accuracy, the proposed method is better than artificial neural network(ANN) under the condition of few categories of training data.

Keywords dual-rotor bearing; fault diagnosis; convolution neural network(CNN); autoregressive model (AR); Kmeans clustering; semi-supervised learning

Diagnosis of Transformer Winding Looseness Based on VMD Morphological Gradient Spectrum and BAS-RF

YAN Jin[1], *MA Hongzhong*[1], *ZHU Hao*[1], *ZHANG Yuliang*[1], *XU Honghua*[2]
(1. College of Energy and Electrical Engineering, Hohai University Nanjing, 211100, China)
(2. Nanjing Power Supply Company, State Grid Jiangsu Electric Power Company Nanjing, 210019, China)

Abstract To effectively extract the state information of winding in the transformer vibration signal, a new method based on variational modal decomposition (VMD) and morphological gradient spectrum is proposed for extracting feature vectors. The beetle antennae search-random forest (BAS-RF) is utilized to recognize the discharge types. First, the measured vibration signals of the transformer windings under three different loose states are decomposed by VMD to obtain several modal components. Then, the multi-scale morphological gradient spectrum is calculated to form the initial characteristic sample. In order to prevent the disaster of dimensionality, the dimension reduction of the feature vectors is carried out by the principal component analysis. Finally, the number of decision trees in the random forest and the depth of the trees are optimized to construct a classifier model using the beetle antennae search to realize the recognition of the loose state of the transformer winding. Experimental results show that this method can effectively extract the characteristic information of transformer winding looseness and has excellent anti-noise performance. The constructed BAS-RF model has a high recognition accuracy and recognition speed.

Keywords transformer; winding looseness; variational mode decomposition(VMD); morphological gradient spectrum; random forest(RF)

Multiple Joint Surfaces Modeling and Dynamic Characteristic Analysis for Planar Ball Screws

LI Zhongkai[1], *SUN Ran*[1,2], *ZOU Guangyu*[1]
(1. School of Mechatronics Engineering, China University of Mining and Technology Xuzhou, 221116, China)
(2. Xuzhou WIKA Electronic Control Technology Co., Ltd. Xuzhou, 221009, China)

Abstract Aiming to improve the transmission efficiency and positioning accuracy of the plane transportation equipment, the normal compression stiffness and tangential motion stiffness of bolt connection interface are determined by using Takashi Yoshimura method for the multi-element assembly interface in x-y axis plane ball screw pair. Hertzian contact theory is used to determine the radial or normal compression stiffness of the contact interface for screw nut, bearing and guide rail. The dynamic model of x-y linear feed system is established based on ABAQUS software. Modal test with hammering method and comparison of literature verify the correctness of the theoretical model and the calculation of the joint surface stiffness in this paper. The influences of the changes of the worktable quality, the distance between the sliding blocks and the distance between the guide

rails on the dynamic characteristics of the plane feed system are studied using numerical analysis methods. Moreover, the design parameters are recommended. The design example of a plane feeding machine tool for medical scissors material verifies the validity of the obtained dynamic system design rules.

Keywords ball screw; plane feed system; joint surface modeling; dynamic characteristics

Effect of Reinforcement Corrosion on Vibration Characteristics of Fixed-End RC Beams

XU Lueqin[1,2], *CHEN Xuxian*[1], *ZHOU Jianting*[2], *WANG Pei*[1], *GAO Peng*[1], *YANG Shanqing*[1]
(1. School of Civil Engineering, Chongqing Jiaotong University Chongqing, 400074, China)
(2. State Key Laboratory of Mountain Bridge and Tunnel Engineering, Chongqing Jiaotong University Chongqing, 400074, China)

Abstract To reveal the influence of steel corrosion on the vibration characteristics of fixed-end reinforced concrete (RC) beams, two groups of RC beams (named S-14 and S-16) with longitudinal reinforcement diameters of 14 mm and 16 mm were respectively fabricated. The two groups are consisted of 8 beams in total with 4 beams in each group. The electrochemically accelerated corrosion method is applied to each group with the target corrosion rates of 0%, 5%, 10% and 15% set for the four beams respectively. Forced vibration tests are then carried out to obtain the vibration characteristics of the 8 beams. Based on the test results, the effects of alternating current and environmental vibration are analyzed on the accuracy of tests, and the influences of corrosion rate and longitudinal reinforcement diameter are studied on the vibration characteristics of RC fixed-end beams. Finally, the relationships between load and frequency, section stiffness and frequency are discussed. The research showes that the interference factors has a negligible effect on the vibration frequency of fixed end beams, but has a certain influence on the damping ratio where the maximum deviation can be 43.62% when subjected to a vibrational environment. As the corrosion rate of longitudinal reinforcement increases, the frequency of fixed-end beam decreases continuously, with the maximum reductions being 16.89% and 8.13% respectively for the groups of S-14 and S-16. The decreasing amount and rate of the vibration frequency become larger when the longitudinal reinforcement diameter is smaller. The damping ratio of beam in the two groups varies in different patterns with the corrosion rate of longitudinal reinforcement. Both theoretical and measured results show that the change rate of fixed-end beam section stiffness due to the steel corrosion is twice that of vibration frequency.

Keywords fixed-end RC beam; vibration characteristics; forced vibration method; steel corrosion; longitudinal reinforcement diameter; section stiffness

Simulation and Experiment Method Based on Trouble Shooting for Reducing the Automotive Acceleration Noise

JIANG Jun[1,2], *LIU Xuelai*[1], *SUN Jianxi*[2]
(1. School of Mechanical and Automotive Engineering, South China University of Technology Guangzhou, 510641, China)
(2. SAIC Motor Corporation Technical Center Shanghai, 201804, China)

Abstract Vehicle accelerating noise is a troublesome issue commonly existing in automobiles. To improve this issue, the characteristics of frequency of accelerating noise are confirmed by real experimental results. The important components which cause the interior noise are identified by the passive side acceleration of the engine mount and the modal of each component on the vehicle. The finite element model of vehicle is established and the model is validated by experimental results. The improvement program is proposed in finite element model and implemented in the vehicle. The results show that the accelerating noise in the vehicle is mainly caused by

the modal of lower tie bar, sub-frame and cowl panel. The accelerating noise is reduced by 8～9 dB after implement the improvement program.

Keywords acceleration noise; modal; finite element model; noise transfer function

Synchronous Identification for Unknown Loads and Parameters of Nonlinear Structures Based on Improved UKF

WANG Zhen[1], *XIN Yu*[1,2], *WANG Zuocai*[1,2], *YUAN Ziqing*[1]
(1. School of Civil Engineering, Hefei University of Technology Hefei, 230009, China)
(2. Anhui Province Infrastructure Safety Inspection and Monitoring Engineering Laboratory Hefei, 230009, China)

Abstract The external loads are usually required to be known when using the traditional unscented Kalman filter (UKF) method for nonlinear system identification. However, in real application, the input of nonlinear structures is difficult to be obtained or the measurement error is large, under this circumstance, the application of the UKF method will be limited. To identify nonlinear structural parameters under unknown excitations, this paper proposes an improved UKF based synchronous identification method for parameters and unknown load identification of nonlinear systems. Based on the proposed method, the unknown loads are firstly estimated based on the predicted values of structural dynamic responses and system parameters, and then, the external loads are further identified based on the updated system state values. In addition, to reduce the negative effects of the measurement noise on nonlinear system identification, a Kalman filter (KF) process is embedded in the UKF method to real-time optimize the measurement noise covariance matrix. To verify the feasible and accuracy of the improved UKF approach, numerical simulations on a single degree-of-freedom (DOF) and five-DOF Bouc-Wen hysteretic models under seismic excitations are conducted. The results show that the improved UKF method can effectively realize the synchronous identification of unknown loads and system parameters of nonlinear structures.

Keywords unscented Kalman filter; nonlinear structure; unknown load identification; nonlinear parameter identification

Experimental Study on the Dynamic Response of Wire Rope Under Lateral Impact Load

FENG Zhujun[1], *WANG Xiuli*[1], *HU Yi*[2], *WANG Sailong*[1], *YAO Yong*[3], *CHU Yunpeng*[3]
(1. School of Civil Engineering, Lanzhou University of Technology Lanzhou, 730050, China)
(2. China MCC17 Group Co., Ltd. Lanzhou, 730050, China)
(3. Shock and Vibration of Engineering Materials and Structures Key Laboratory of Sichuan Province, Southwest University of Science and Technology Mianyang, 621010, China)

Abstract In order to study the dynamic response of wire rope under lateral impact load, the impact tests of single wire rope and wire rope mesh are carried out respectively, and the effects of surface state, material, diameter and connection mode on the impact resistance of steel wire rope are considered. Combined with the tensile test of the material, the static and dynamic properties of the wire rope are compared. The static tensile results show that different surface states and materials only affect the deformation capacity of wire rope in the elastic stage but have little effect on the bearing capacity of wire rope. There are three kinds of damage to wire ropes under impact load: local damage of an impact point, failure of connection part, and fracture. The dynamic impact test shows that the surface state and material of wire rope only affect the elastic modulus under static tension, but have little effect on the impact resistance of wire rope. For single wire rope impact test conditions, when the same impact material is impacted, the strain value at the middle of the wire rope with a smaller diameter is larger, and the strain value at the end of the wire rope with a larger diameter is larger. The buckle-connected

wire rope has gone through three different stages from the relaxed state to the tensioned state and then to the loaded state while the bolted wire rope directly starts from the tensioned state to the loaded state. The deformation of the buckle-connected wire rope is larger than that of the bolted connection, and it is prone to failure when subjected to strong impact loads, leading to low connection reliability.

Keywords wire rope; lateral impact; dynamic response; impact resistance

Testing and Mechanical Modeling of Magnetorheological Elastomer Shock Absorber

LIU Qiang[1,2], *XU Kai*[1], *ZHAN Xiaoming*[2], *ZHENG Tao*[2]

(1. Engineering College, Ocean University of China Qingdao, 266100, China)

(2. Zhejiang Huadong Mapping and Engineering Safety Technology Co., Ltd. Hangzhou, 310014, China)

Abstract The mechanical properties of magnetorheological elastomers (MRE) exhibit complex nonlinear characteristics. The key of intelligent vibration control is to establish the mechanical model of MRE shock absorber to characterize its dynamic characteristics. Aiming at the problems of parameter identification of parametric model and local optimization of nonparametric model, according to the experimental results of mechanical characteristics of MRE shock absorber, a back propagation (BP) neural network model optimized by mind evolution algorithm (MEA) is established to describe the mechanical characteristics of MRE shock absorber, and the differences between parametric modeling and nonparametric modeling are compared. The results show that the linear K-C model can only describe the linear mechanical properties of MRE shock absorber, while the Bouc-Wen model can accurately describe the nonlinear mechanical properties of its central symmetry, MEA-BP neural network can accurately predict the nonlinear mechanical characteristics of MRE shock absorber. The research results provide a reference for the design and application of MRE shock absorber.

Keywords magnetorheological elastomer shock absorber; mind evolutionary algorithm; BP neural network; mechanical modelling

Impedance Analysis of Tuned Vibration Absorbers for Oil Pipeline Vibration Control

MA Yu[1], *TENG Handong*[2]

(1. Production and Operation Department of Pipe China Network Corporation Eastern Oil Storage and Transportation Co., Ltd. Xuzhou, 221008, China)

(2. Aerospace Engineering College, Nanjing University of Aeronautics and Astronautics Nanjing, 210016, China)

Abstract In order to solve the problems of weld cracking and fatigue failure of pipeline joints caused by severe vibration of oil pipeline, the impedance coupling method and dynamic vibration absorption technology are adopted to realize the vibration reduction of the oil pipeline. The vibration absorber using metal bellows is installed on the pipeline with the help of a hoop. It can achieve vibration reduction in three directions (x, y and z) of the pipeline and has the advantages of explosion-proof, flame-retardant, and three-dimensional vibration reduction. Comparing the root mean square values of vibration acceleration at the same measuring point before and after vibration reduction, it can be seen that the vibration reduction effect of the pipeline reaches over 64.9%. The reduction of the pipeline vibration can reduce the action of alternating stress and the fatigue damage. This vibration reduction scheme does not require dismantling of the inlet and outlet pipelines, only needs to install vibration absorbers outside, which suggests that the vibration absorption technology is a better method for the vibration control of the oil pipeline.

Keywords oil pipeline; impedance; dynamic vibration absorber; vibration control

OFDR Distributed Optical Fiber Impact Localization Method of Composite Laminate

ZHONG Zhaozhen[1], *ZENG Jie*[1], *LI Yanfen*[2], *BAI Yufang*[1], *HUANG Jiwei*[1], *QI Lei*[3]
(1. State Key Laboratory of Mechanics and Control of Aerospace Structures, Nanjing University of Aeronautics and Astronautics Nanjing, 210016, China)
(2. Beijing Institute of Structure & Environment Engineering Beijing, 100076, China)
(3. Beijing Institute of Spacecraft Environment Engineering Beijing, 100094, China)

Abstract Aerospace vehicle structures based on composite materials are easily damaged by impacts from external objects during service. The conventional fiber Bragg grating impact monitoring mode requires a large number of experiments to establish an impact response sample library, which not only requires a lot of work, but also affects the mechanical properties of the tested structure and even causes pre-damage. For this reason, this paper proposes a method for identifying the impact position of distributed optical fiber based on the principle of nonlinear weighting of strain amplitude. The method extracts the structural strain response amplitude as the characteristic quantity, and combines the principle of nonlinear weighting without prior samples to realize the impact load position identification. With the aid of finite element numerical simulation, the strain response and distribution characteristics of composite laminate structure under impact load are simulated, and the identification method is verified according to the simulation results. An impact monitoring system based on a high spatial resolution distributed optical fiber sensor is constructed, and the average positioning error is about 8.44 mm. Research shows that the method proposed in this paper has the characteristics of easy integration, strong versatility, and no need to build a sample library, and can provide technical support for the structural health monitoring, life evaluation and rapid maintenance of spacecraft.

Keywords composite laminate; distributed optical fiber sensor; impact localization; nonlinear weighting; strain response

Fault Response of Sun Gear in Time Varying Path Planetary Gearbox Periodic Characteristics

ZHANG Xulong, *JIANG Hong*, *ZHANG Xiangfeng*, *LI Jun*, *SHEN Yong*, *DING Tao*
(School of Mechanical Engineering, Xinjiang University Urumqi, 830047, China)

Abstract This paper focuses on the periodic influence of time-varying path characteristics on the fault meshing response of the sun gear, and verifies the data length that can characterize different fault types of the sun gear. The position sensor is used as the observation point of the periodic variation of the fault engagement of the sun gear, taking the speed ratio of the sun gear and the planet carrier as the starting point, and whether there is a difference classification between the planet gears, the expressions of the meshing period of the same gear teeth and the meshing period of quasi-identical gear teeth are derived respectively, and the relationship between them is proved. According to the derivation period and its multiple, different types of fault signals of the sun gear are intercepted, and the characteristics are taken to establish a three-dimensional space to distinguish the fault types. The results show that one time of the meshing period of the same gear teeth is the minimum length to represent different types of faults of the sun gear, and two times of the meshing period of the same gear teeth is the best length to represent different types of faults of the sun gear. With the help of the periodicity of the meshing response of the sun gear fault, the diagnosis of different types of faults of the sun gear can be realized.

Keywords sun gear; revolution speed ratio; fault diagnosis; time-varying path; meshing period of quasi-identical gear teeth; meshing period of the same gear teeth

Vibration Characteristics Analysis of Constrained Damped Cylindrical Shell Considering Interlayer Deformation

MA Hongwei[1,2], *CHEN Zhongshi*[1,2], *SUN Wei*[1,2]

(1. School of Mechanical Engineering & Automation, Northeastern University Shenyang, 110819, China)

(2. Key Laboratory of Vibration and Control of Aero-Propulsion Systems Ministry of Education, Northeastern University Shenyang, 110819, China)

Abstract In a structure with constrained damping, the middle viscoelastic layer mainly depends on the staggered motion of the substrate and the constrained layer to produce shear deformation and dissipate energy, so an effective approach for introducing interlayer deformation relationships is necessary to improve modeling accuracy. Therefore, the finite element method is used to investigate the dynamic modeling method of cylindrical shell with partial constrained layer damping. Firstly, based on Donnell's thin shell theory, the stiffness and mass matrices of the composite element are derived by considering the deformation relationship between each layer. Next, a transition element is constructed to connect the composite shell element and the single layer element with only substrate, and the effective assembly of the total stiffness and total mass matrices for cylindrical shell structure with partial constrained layer damping is realized. Furthermore, considering the elastic constrained boundary conditions of composite cylindrical shell, the motion equation of composite shell is determined, and the formula for solving its vibration characteristics is provided. Finally, a case study is conducted to verify the accuracy of the proposed finite element model by comparing it with experimental and ANSYS simulation results. The influence of thickness on both constrained layer and viscoelastic layer on the vibration and damping characteristics of composite cylindrical shell are further analyzed.

Keywords interlayer deformation relationship; partial attachment; constrained layer damping; cylindrical shell; vibration characteristics; finite element modeling

Analysis of Shock Response Robustness for Effect Target Sheet with Peripheral Fixed Support

ZHAI Hongbo, *LI Shangqing*, *MAO Boyong*, *DING Gang*, *SU Jianjun*

(Xi'an Modern Chemistry Research Institute Xi'an, 710065, China)

Abstract The characterization method and the limit state function of the deformation robustness for the effect target sheet with peripheral fixed support are established via the shock response calculation model. Then, the analytical algorithm of the deformation robustness for the sheet is proposed based on the Monte-Carlo sampling estimation. Consequently, the influence of the sampling times, geometric parameters, load parameters, material parameters on the deformation robustness and sensitivity is researched. The results show that the deformation robustness tends to be stable when the sampling times is greater than 300 000. It is illustrated that the deformation robustness is strong nonlinear. The deformation robustness of the sheet reduces as the radius-thickness ratio and thickness increase. The sensitivity of the standard deviation of the thin plate radius on the deformation robustness is the greatest, which is the main control parameter of the deformation robustness. The study in this article is valuable for the design and pressure measurement application of the effect target with peripheral fixed support.

Keywords effect target; shock response; deformation robustness; peripheral fixed support

《振动、测试与诊断》第九届编委会

《振动、测试与诊断》编辑部