Method for Suppressing Vibration During the Position/Force Switching of the Interaction Between a Robotic Arm and the Environment

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Abstract When a robotic arm performs a mixed tracking task of position/force, position control is generally used for the free motion stage of the robotic arm, while force control is generally used for the constrained motion stage. This control structure of position/force switching can achieve the precise control of the robotic arm's position before contact with the environment, and ensure the accurate tracking of the desired control force after contact. However, due to the switching instability of the switching system itself, the robotic arm's actuators may vibrate or even bounce on the surface of the environment when the robotic arm contacts with the environment at a certain speed. To address this issue, a semi-active damping impedance learning method is proposed, which mainly consists of two parts: a semi-active damping controller based on the position/force switching control; an impedance learning algorithm based on a broyden-fletcher-goldfarb-shanno (BFGS) method, which adjusts the semi-active damping according to the learned environmental parameters to suppress vibration and ensure a smooth transition of the robotic arm on the contact surface. In simulations and experiments, the proposed method is applied to enable the robotic arm to interact with different environments, and the results show that the method can effectively suppress overshooting force during the contact transition stage, prevent vibration during the switching process, and achieve smooth contact and transition.

Keyworks position/force hybrid tracking; switching controller; semi-active damping; broyden-fletcher-goldfarb-shanno (BFGS) method; vibration suppression

An Optical Fiber Technique of Impact Load Identification Method Based on Non-negative Bayesian Regularization

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Abstract An optical fiber technique of impact load identification method of composite structure based on non-negative Bayesian regularization is proposed in terms of the problems existing in impact load identification. For example, the quality of sensors cannot be ignored and the identification result has negative component. Firstly, the fiber Bragg grating (FBG) sensor is integrated into the composite tube structure to obtain its dynamic response signal. Secondly, the impact load identification model is established to represent the impact load identification problem as deconvolution problem of discrete-time. Taking into account the non-negative characteristics of the impact load, its posterior probability density function is obtained through Bayesian hierarchical model. then the maximum posterior probability solution for the impact load is obtained by maximizing probability density function. The results show that the simultaneous measurement of impact response at multiple sensing points can be achieved by FBG sensors, and the non-negative Bayesian regularization method can effectively overcome the shortcomings of traditional Tikhonov regularization, adaptively determine the algorithm parameters, eliminate the negative components which have no physical meaning. Therefore, the reconstructed time history of impact load can coincide with the actual time history.

Keywords load identification; composite structure; fiber Bragg grating; non-negative Bayesian regularization

Design and Experimental Study of a Novel Inchworm Piezoelectric Linear Actuator

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Abstract Considering the piezoelectric actuators have characteristics of wide temperature resistance range, no electromagnetic interference, and self-locking when powered off, a novel inchworm piezoelectric linear actuator, which meets the demand of new actuators for small grasping operating mechanisms in the aerospace environment, is proposed imitating the walking mode of the insect inchworm. A flexible hinge-type displacement amplifying mechanism is utilized to amplify the output displacement of the Pb-Zr-Ti (PZT) stack, so as to increase the movement step length of the linear actuator and the clamping deformation of the guide rail. The multiple PZT stacks are divided into three groups, which are respectively used as two clamping units and one propulsion unit of the actuator to obtain a larger driving force and further increase the movement step. Through the finite element analysis method, the prediction method of the electromechanical coupling behavior of the PZT stack is studied, and the feasibility of the method is verified by experiments. The flexible hinge displacement amplification mechanism is simplified, and the numerical analysis method of magnification is proposed. On this basis, an experimental study is carried out based on the designed linear actuator. The test results show the magnification of the output displacement of the PZT stack by the displacement amplifying mechanism is 7.3, which is between the theoretical value and the simulation one. When the excitation voltage frequency is 5 Hz, the maximum no-load moving speed of the actuator is 413 μm/s; the maximum driving force is 16 N, corresponding to a driving speed of 19 μm/s. The above research results can provide technical support for the intelligent drive of small grasping operating mechanisms.

Keywords inchworm type; piezoelectric actuator; PZT stack; displacement amplification; self-locking when power off

Cause Analysis of Rail Corrugation in Vehicle Starting Section of Metro

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Abstract In order to study the cause of rail corrugation in the straight starting section near the metro exit, the transient rolling contact model of three-dimensional solid wheelset-track is established by using the finite element software ABAQUS, and the corrugation phenomenon is analyzed in time-domain and frequency-domain based on the field measurement. The results show that, during the starting of the vehicle, the quasi-periodic sliding zone can be produced in the contact surface between wheel and rail, and the distance between the centers of sliding zones is close to the wavelength range of the measured corrugation, which verifies the rationality and effectiveness of the model. The unstable friction self-excited vibration of wheelset-track system is the fundamental cause of rail corrugation in the measured section, and it is precisely because of the "saturated-unsaturated" periodic characteristic of wheel-rail creep force that ultimately promotes the formation of rail corrugation. The vertical vibration acceleration levels of rail and wheel have a peak area in the frequency range of 160～230 Hz, and the frequency range is close to the characteristic frequency range of 174～198 Hz of the measured corrugation, which further indicates that the rail corrugation is caused by the wheel-rail resonance from the friction self-excited vibration of wheelset-track system. On the premise of ignoring the initial irregularity, the corrugation on rail surface shows a linear growth trend with the increase of wheel operation times. Therefore, it is very important to take appropriate measures such as rail grinding and rail surface lubrication.

Keywords metro; starting section; rail corrugation; transient rolling contact model; sliding; friction self-excited vibration

Damage Detection Method of Suspension Bridge Based on Index of Strain Impact Factor

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Abstract In order to achieve rapid detection of large-span suspension bridges, an improved damage detection method is proposed based on dynamic amplification coefficients. Firstly, the damage index is constructed by comparing the impact factor of intact and damaged bridges, where the baseline data of intact bridges are obtained by a program of vehicle-bridge coupling vibration. Then, the peak value and overall trend of the damage index of the bridge are analyzed to locate the damage and evaluate the damage degree. The effectiveness of the method for bridge damage localization and quantification is verified through numerical simulations and tests on a scaled-down model of suspension bridges. Both numerical simulations and test results show that the method can accurately locate the damage of suspension bridges and realize the quantitative analysis of the damage degree. The difference between the damage index of the damaged bridge and the intact bridge is used to assess the damage of the bridge, which can eliminate the influence of the bridge surface irregularity on the damage identification. This method has strong anti-noise ability and a good prospect of engineering application.

Keywords suspension bridge; impact factor; vehicle-bridge coupling vibration; damage detection

Dynamic Response and Energy Conversion Mechanism of VLFS in Marine Airport Under Typhoon Waves

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Abstract Very large floating structure (VLFS) is a large multifunctional floating structure integrating airport and seaport. Most of the existing studies focus on the dynamic response of rigid module flexible connection model under regular waves, but ignore the dynamic response caused by the flexibility of maritime airport under typhoon driving waves. Given this, a new modeling method of flexible module rigid connection of VLFS is proposed. The measured wave spectrum of typhoon Migi is finely simulated by using Jonswap spectrum characteristic parameters. The overall and local nonlinear vibration characteristics of VLFS in maritime airport under typhoon driving waves are analyzed, and the energy conversion mechanism between maritime airport and environmental load is revealed. The results indicate that flexible module rigid connection model of maritime airport can better reflect the dynamic response characteristics of such VLFS structures. The maritime airport is significantly nonlinear due to structure flexibility and the inhomogeneity of the typhoon and waves field. The displacement, angle and hydroelastic deformation are mainly along the flow direction, spanwise direction and vertical direction respectively, and the extreme stress is mainly distributed near the strut of VLFS. The environmental load energy and structural gravity potential energy are mainly converted into mooring potential energy in the initial stage, and structural kinetic energy and elastic potential energy in the stable stage.

Keywords typhoon waves; maritime airport; super large floating structure (VLFS); dynamic response; energy conversion mechanism

Multi-mode Coordinated Switching Control of Electromagnetic Hybrid Active Suspension

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Abstract Aiming at the problem that the output force of the active suspension of linear motor is relatively small, the hybrid active suspension structure and multi-mode coordinated switching control strategy are designed. The global search ability and local development ability of the gravity search algorithm are improved by dynamically adjusting the gravity constant, which solves the problem that the gravity search algorithm is prone to premature convergence and falling into local optimization The fitness function is set up according to the different control objective, and the weighted coefficients of linear quadratic gaussian (LQG) control are optimized by using the improved gravity search algorithm. The optimal control currents of the electromagnetic hybrid active suspension at different vehicle speeds are analyzed and determined; the current switching controller is designed, and the vibration reduction performance of the suspension is simulated and analyzed. The simulation and test results show that compared with the LQG control, the root mean square value of the spring load mass acceleration at low speed and the dynamic tire load at high speed is reduced by 31.09% and 32.20% respectively, the root mean square value value of the mass acceleration of the spring and the dynamic load of the tire are reduced by 25.28% and 23.56% respectively, and the control strategy can effectively improve the ride and handling stability of the vehicle.

Keywords active suspension; gravitational search algorithm; multi-mode; linear quadratic gaussian (LQG) control

Multi-sensor Fusion Positioning System and Experimental Study of Roadheader

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Abstract The autonomous and accurate positioning of roadheader is the foundation of intelligent development of coal mine roadway excavation. However, the complicated tunneling technology and harsh tunneling environment make the positioning of roadheader faces problems such as insufficient autonomy, low accuracy and poor immunity to disturbance. In order to realize the autonomous and accurate positioning of roadheader, an odometer-aided inertial positioning system is constructed based on extended Kalman filter to restrain the error divergence of pure inertial positioning. Combined with the construction technology of roadheader, a flexible zero velocity updating method is proposed to further improve the inertial positioning accuracy of roadheader. The efficient integration of inertia, vision and mileage positioning is realized based on error state Kalman filter and multi-state constraint model. A prototype test system of roadheader in dark environment is also built. The experimental results show that the proposed flexible zero velocity updating method can improve the pure inertial positioning accuracy by 21.64%. The three-axis positioning errors of the proposed multi-sensor fusion positioning system of roadheader are within 0.13 meters of lateral positioning error, 0.17 meters of forward positioning error and 0.02 meters of upwards positioning error, which improves by 49.62% and 57.71% compared with the independent inertial and visual systems, respectively. The experimental results verify the feasibility and effectiveness of the proposed method and system, and the positioning accuracy of the proposed system meets the requirements of roadway excavation in coal mine.

Keywords autonomous positioning; inertial navigation; multi-state constraint; visual and inertial fusion

Detection Framework of Wheel Polygon Wear State Based on Iterative Modified DFT

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Abstract Affected by the variable speed operation of vehicles, random irregularity of tracks and other factors, the operation process of rail vehicles is a typical non-stationary process. It is difficult to accurately identify the wheel polygon wear order and amplitude, because the traditional methods are not ideal for non-stationary processing signals. A dynamic detection framework based on iterative modified discrete Fourier transform (DFT) is proposed to improve the detection accuracy of wheel polygon wear state. The vertical vibration acceleration signal of axle box is used for analysis, when the vehicle is running at a relatively stable speed. Firstly, relatively stationary short-time signals are extracted from the sample signals by setting appropriate stability test conditions. Secondly, the frequency domain analysis and iterative calculation of the extracted short-time signal are carried out to obtain each order wheel polygon's vibration frequency and period. Then, according to the length of the vibration period, the extracted short-time signal is truncated twice to obtain a new short-time signal representing an integer multiple of the wheel polygon's vibration period. Finally, combined with the geometric and dynamic characteristics of the wheel polygon, the frequency domain analysis and wear parameters (order and amplitude) of the extracted new short-time signal are calculated again to realize the accurate identification of the wear state of the wheel polygon. The verification analysis shows that the identification framework effectively reduces the identification error caused by inherent defects such as the fence effect and spectrum leakage in traditional analysis methods, eliminating the interference of most non-stationary factors and provide theoretical support and method reference for rail vehicles' safe operation and maintenance.

Keywords railway vehicle; wheel polygon; wear; detection; discrete Fourier transform

Continuous Scanning Laser Testing Method for Operational Deformation Shape of the Flat Plate Structure with Circle Holes

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Abstract A method of laser continuous scanning Doppler testing based on sub region division and mode reconstruction is proposed to measure the operational deformation shape of flat plate structure with arbitrary circular holes. Firstly, the surface of a flat plate structure with arbitrary circular holes is divided into several sub regions, which are completely covered by rectangular and circular scanning. The operational deformation shape of each sub region is obtained by using constant speed linear continuous scanning and spiral scanning methods respectively. Then, considering the problems of amplitude ratio, different reference plane and rotation angle, and reverse vibration on both sides of the pitch diameter, the operational deformation shape of all sub regions is spliced and reconstructed to obtain the operational deformation shape of the whole structure. Finally, compared with the simulation results, measured modal assurance criterion (MAC) values are greater than 0.95, verifying the effectiveness of the method. This method can realize the continuous scanning laser vibration test of flat plate structure with arbitrary circular holes, and thus has the advantages of high efficiency and dense measuring points. It plays an important role in further improving the application scope of its engineering applications.

Keywords circular hole; continuous scanning; laser Doppler; sub region division; mode reconstruction

Fault Prediction Method of Track Circuit Based on Fuzzy Clustering and CNN-BIGRU

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Abstract Aiming at the problem of insufficient timeliness of fault diagnosis of track circuit in steady-state environment, a method based on Gath-Geva (GG) fuzzy clustering to divide the degraded state of track circuit is proposed, and the fault prediction of track circuit is carried out by using convolutional neural network (CNN) and bi-directional gated recurrent unit (BIGRU). Firstly, through the centralized monitoring equipment, the normal working data of each fault type of ZPW-2000 track circuit within a certain time before the fault occurs are obtained. Then, the performance degradation states of track circuit are divided into stages by feature reduction and GG fuzzy clustering based on kernel principal component analysis, and different degradation states are identified. Finally, CNN-BIGRU hybrid neural network is used to mine the data characteristics of different fault types of track circuit, predicting the fault types corresponding to the degraded state of track circuit. Experimental results show that the algorithm can accurately divide the degraded state of track circuit and realize its fault prediction. The classification accuracy of CNN-BIGRU prediction model can reach 97.62% and the running time is only 13.18 s. It can provide an effective method for multi-mode health state recognition of track circuit.

Keywords track circuit; GG fuzzy clustering; degradation state division; convolutional neural network - bidirectional gated recurrent unit (CNN-BIGRU); fault prediction

Magnetic Disturbance Method to Measure Oxide Scales Blockage in Ferromagnetic Boiler Tubes

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Abstract In order to solve the difficult problem of detecting the oxide scales blockage in ferromagnetic boiler tubes, a non-destructive testing method called magnetic disturbance method was proposed. Numerical simulation is used to analyze the magnetic field distribution characteristics of the ferromagnetic boiler tube under the action of two electromagnets placed orthogonally, and experiments have been done to verify the correctness of the simulation results. The acoustic emission technology is applied to collect the sound generated by the hitting of oxide scale towards the tube wall under the magnetic field, thereby establishing the quantitative relationship between the waveform characteristic parameters and the radio of oxide scales blockage area. Test results indicate that the two electromagnets form a unique magnetic field in the pipe that can penetrate the pipe wall and directly attract the oxide scales because of the non-linear characteristics of the magnetic permeability of the ferromagnetic boiler pipe. The attraction limit of this method is as low as 10% oxide scales blockage area. Moreover, the weighted average time of acoustic signals weighted by the absolute value of amplitude can be used to judge whether the ratio of oxide scales blockage area of the inspected pipe exceeds the standard, which indicates the proposed method has engineering application prospects.

Keywords magnetic disturbance method; ferromagnetic boiler tube; oxide scale; acoustic emission; nondestructive testing

Remaining Useful Life Interval Prediction of Mechanical Equipment Based on FA-LN-BiGRU

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Abstract Prediction models based on deep learning methods is difficult to measure the uncertainty of the remaining life of mechanical equipment. In particular, statistical data-driven predictive models are difficult to describe the coupling relationship between multi-dimensional sensor data. And the data-driven fusion model has the problem of loss of key information. To solve these problems, an end-to-end remaining useful lifetime interval prediction method is proposed based on feature attention-lognorm-bidirectional gated recurrent unit (FA-LN-BiGRU). First, the feature attention mechanism is used to extract key feature vectors from multi-dimensional, nonlinear and large-scale sensor signals. Then, the BiGRU network is used to model the time-varying characteristics of the attention-weighted features from both forward and backward directions. And the network parameters are trained through the maximum likelihood estimation loss function to obtain the probability distribution of the network hidden state output vector. Thus, the probability density function based on log-normal distribution is calculated to realize the measurement of equipment remaining useful life (RUL) uncertainty. The analysis results show that the proposed method can deeply mine performance degradation information for multi-dimensional monitoring data with complex operating conditions and variable failure modes. The accuracy and reliability of the remaining life point prediction and interval prediction of mechanical equipment are effectively improved.

Keywords remaining useful life prediction; log-normal distribution; fusion prediction model; interval prediction; feature attention mechanism

Correction of the Target Dummy Vehicle Chassis Rolling Model Based on Parameters Reverse Method

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Abstract Aiming at the problem of simulation and analysis of rolling performance in the design and development of the chassis structure of a target dummy vehicle, the nonlinear dynamics finite element method is used to simulate the rolling performance of the chassis. Calculated results are compared with the experimental results, and the reasons for the large error are analyzed. Parameters of the wheel model of the experimental vehicle in the chassis rolling model are modified by the parameters reverse method, and the optimal solution of the wheel model parameters is obtained based on genetic algorithm. Based on the modified parameters according to the optimal solution of the wheel model parameters, the fitting degree of the simulation results and the experimental values of the modified wheel parameters are greatly improved. The maximum displacement error of the measurement point is reduced from 16.7% to 2.6%, and the root mean square error of the evaluation point is reduced by 91.9%. The accuracy of the simulation analysis results of the target dummy vehicle chassis rolling has been greatly improved, which provides a reference model for the subsequent structural damage diagnosis and structural optimization simulation research.

Keywords intelligent vehicle test platform; parameter reverse method; target dummy vehicle chassis; rolling simulation; model correction

Gear Wear and Contact Fatigue Competitive Failure Model

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Abstract In order to calculate gear reliability, the failure probability models is established aiming at the two common failure modes of wear failure and fatigue failure, respectively. The reliability is calculated based on the results of the failure probability. The effects of the shocks following the Poisson process on wear and contact stress are considered. The wear-wear threshold interference model is established in the form of cumulative wear. Considering random strength degradation, the dynamic strength-stress interference model is established. With a numerical example for gears in the reducer, the reliability analysis is conducted. Verified by this numerical example, the gear reliability results of the two failure modes considering the shock are obtained. Additionally, reliability values under different shock parameters are analyzed. The results show that the model can provide specific guidance to life estimation, material selection and other engineering issues.

Keywords component reliability; wear failure; fatigue failure; interference model

Dynamic Modeling and Feedforward Compensation of the Rate-Dependent Bipolar Bias Hysteresis Nonlinearity of Marco Fiber Composites Actuators

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Abstract Compared to conventional piezoceramics, marco fiber composites (MFC) offers excellent advantages of high deformation abilities and energy transducing efficiencies. MFC actuators have been widely used in deformation control and bionic actuation of flexible structures. A rate-dependent bipolar bias PI (RDBBPI) hysteresis model is presented to describe the dynamic hysteresis nonlinearity of MFC actuators, and feedforward compensation control based on the proposed RDBBPI model is also conducted. The classical PI model is used to describe the symmetric hysteresis behavior of the MFC-actuated flexile structure. A series of dead-zone operators is superposed to the PI model to capture the bipolar bias nonlinearity. Accordingly, a quasi-static bipolar bias PI hysteresis model is presented. Then, the linear relationship between slope of the hysteresis loop and velocity of the driving voltage is established. The RDBBPI hysteresis model for the dynamic hysteresis of MFC actuators is obtained. Experimental results show that the proposed RDBBPI model is capable of describing the dynamic hysteresis behavior of the MFC-actuated flexible structure, under different actuation frequencies. With the compensated controller based on the RDBBPI model, measured vibration displacements of the flexible structure match well with the desired tracking trajectories. The compensated linearity error between the actual trajectory and the desired one is only 4.62%. Therefore, the feasibilities of the proposed RDBBPI hysteresis model and feedforward compensation method are demonstrated.

Keywords macro fiber composites (MFC) actuator; dynamic hysteresis nonlinearity; rate-dependent; bipolar bias; feedforward compensation

Simulation of Non-stationary Measured Wind Velocities Based on Adaptive Time-Frequency Interpolation

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Abstract The classical spectral representation method (SRM) based on theoretical spectrum can effectively simulate most wind velocities in nature. However, it has great deviation and low simulation efficiency as applied to the simulation of extreme non-stationary measured wind velocity. To solve this problem, this paper takes typhoon "Dujuan" (weak non-stationary) and measured downburst (strong non-stationary) as the research background. Taking the measured wind velocity spectrum as the target, the theoretical spectrum is modified, and the simulation scheme based on the modified spectrum is established to make the simulated wind velocity more close to the measured wind velocity. Time-frequency interpolation technology is introduced into the simulation of wind velocity based on modified spectrum. And an adaptive interpolation-enhanced scheme is devised, which uses "average resolution" as the quantization index. The automatic determination of non-uniform distribution of interpolation points in time and frequency domain is realized, which avoids the local precision loss in time and frequency domain and the trouble of testing interpolation parameters manually. The final simulation results are very close to the measured wind velocities, the time-domain characteristics and power spectrum characteristics of the non-stationary measured wind velocity are well retained. Moreover, the introduction of interpolation technology, the simulation efficiency is improved by about 78%, when the error loss is reduced by about 76%.

Keywords measured downburst; spectral representation method; modified spectrum; time-frequency interpolation; adaptive scheme; non-uniform distribution

Study of Data Generation Methods for Rotating Equipment Data Imbalance Problem

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Abstract In operation status monitoring as well as fault identification for rotating equipment, collected fault samples are mostly fault-free samples with few fault samples, and this imbalance in data distribution can have a serious impact on the accuracy of classifier identification. To address this problem, a minority sample data generation method is proposed based on Fourier transform and Pearson correlation coefficient optimization of generative adversarial neural network (FP-GAN). Such method is able to improve the accuracy of fault diagnosis training and recognition by expanding the fault minority samples. Fourier transform is used for getting the single side spectrum of the signal frequency domain, and GAN network is used for generating the signal frequency domain. After that, the generated data is optimized by Pearson correlation coefficient to obtain data closer to the real data by inverse Fourier transform. The validation of simulation and experimental data show that the data samples generated based on FP-GAN can be better integrated with the existing actual data in terms of time-domain features, time-domain statistical features and classifier classification results, which can effectively solve the data imbalance problem.

Keywords generative adversarial neural networks; single side spectrum; Pearson correlation coefficient; inverse Fourier transform; data imbalance

Performance of Support Buffering Seat Based on Semi-active Magnetorheological Damping Control

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Abstract During landing or falling of the aircraft, the human body is usually injured by the shock, and buffering seat is used to reduce the shock of the human body. In order to analyze the shock isolation performance of buffering seat, a mathematical model of buffering seat is established, and the system differential equation of motion is established based on the Lagrange equation. Then, based on the established differential equation of motion, the effects of the system stiffness, damping, and different drop heights on buffering seat are analyzed. The effects of the installation style of the magnetorheological damper on the buffering seat on shock isolation performance are analyzed. The semi-active control is realized by T-S fuzzy model, with the fuzzy control the comparison of the system limit buffering distance response and the optimal buffering response are analyzed. Finally, the buffering seat prototype is tested by drop shock machine to complete the verification of the above theoretical calculation data. The results show that, compared to traditional linear buffers, buffering seat based on semi-active damping control could adapt to different drop heights and improve the buffering performance of the system.

Keyword magnetorheological; drop impact; semi-active damping control; buffering seat

Stability Prediction of Roadheader Cutting System Based on Vibration Model

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Abstract The cutting process of roadheader is affected by dynamic radial and axial loads, and the cutting arm will swing in both horizontal and vertical directions. The cutting vibration generated by the reaction force of coal rock in the swing cutting process has the greatest impact on the pick, and its vibration directly affects the stability of the cutting head. In order to judge whether the cutting load is stable or not, firstly, based on rock fracture mechanics and coal-rock breaking theory, the physical constitutive model of roadheader cutting system is established, and the cutting load spectrum function of pick and cutting head is constructed. Secondly, based on the Newton difference polynomial method, the cutting stability of the cutting process is predicted, and the dynamic equation of the multi-factor coupled nonlinear cutting system is constructed to solve the cutting curve of the dynamic vibration stability domain (the cutting stability lobe diagram). A dimensionless cutting vibration criterion based on correlation coefficient is proposed to determine the cutting state of cutting head at different time from both theoretical and physical aspects. Finally, by setting up the cutting system test bench, the modal parameter identification experiment of the cutting system is carried out, the random load characteristics of the cutting head cutting teeth in the rock breaking process are tested, and the cutting load variation law under different cutting parameter combinations is studied. The best matching relationship between the cutting head speed and the cutting depth is obtained, which proves the correctness of the cutting stability lobe diagram.

Keywords cantilever roadheader; cutting load spectrum; stability lobe diagram; Newton polynomial; cutting stability prediction

Vortex Induced Vibration and Aerodynamic Characteristics of Flat Streamline Box Girder

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Abstract In order to find out the influence of the attached components on the vortex induced vibration and aerodynamic characteristics of flat streamlined box girder, the main girder of a quasi streamlined bridge is selected as the research object. By increasing or decreasing the attached components of the model to simulate the bare beam and non bare beam sections, the wind tunnel pressure and vibration tests are carried out under different wind attack angles. The results show that the vortex induced vibration characteristics of the flat streamlined box girder are greatly affected by the auxiliary components of the model, and the railing section is more prone to vortex induced vibration at the positive angle of attack. At the same angle of attack and wind speed, there is a more obvious predominant frequency of the railing section, which indicates that the attached components of the model will have a greater impact on the vortex shedding of the flat streamlined box girder. The average wind pressure coefficient of flat streamlined box girder is greatly affected by the model section, but the fluctuating wind pressure coefficient is affected by the model section and wind attack angle. Different model sections will affect the average three component force coefficient of flat streamlined box girder, but its variation trend is mainly related to the wind attack angle.

Keywords wind tunnel test; quasi-streamline box girder; vortex induced vibration; pressure coefficient; aerodynamic force coefficient

Fault Detection of Rolling Bearing Based on Fast-SC and EC

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Abstract The key of demodulation analysis is to accurately find a suitable frequency band to demodulation. A demodulation frequency band determination method based on the fast spectral correlation (Fast-SC) and the crest of envelope spectrum (EC) is proposed to extract the feature frequency of fault rolling bearings. Firstly, signal is performed by Fast-SC algorithm. Considering the difference between theoretical fault frequency and actual fault frequency caused by slip, the integrated spectrum correlation section of theoretical fault frequency interval of bearing is adopted as the target spectrum correlation curve. The center frequency search center of the demodulation frequency band according determined to its maximum value. Then, the EC is used as the bandwidth optimization indicator to adaptively obtain the optimal filter parameters. Finally, the signal is bandpass filtered according to the obtained filter parameter set, and its envelope spectrum is obtained to realize bearing fault feature extraction. Simulation and experiment results show that compared with the Autogram demodulation algorithm, the proposed method has better noise reduction ability and better choice of demodulation frequency band.

Keywords demodulation frequency band; feature frequency; fast spectral correlation; crest of envelope spectrum; integrated spectral correlation slices

Bridge-Train-Passenger Coupling Vibration and Riding Comfort Analysis of Urban Track Line

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Abstract The purpose of this research is to improve the running safety and riding comfort of urban rail transit. A typical continuous box bridge in the Beijing Metro line 5 is selected. A coupling vibration model of bridge-vehicle-passengers is established, and the differential equations of motion are deduced, then a corresponding calculating program is written. The dynamic deflections of the bridge, train, and passengers are calculated exactly. The changing safety of the maximum values of each responses, and the running stability and safety indexes of the train are analyzed, too. The reliability of the simulation model and calculating program are verified by the monitored data. The results proved that the selected bridge is in pretty well working conditions. The vibrating acceleration, lateral forces, offload factor, and derail factor of train are quite perfect at current running speed. There are obvious differences between passengers' vibration responses and the vehicles', and there is a little hysteresis. Dynamic responses of passengers sitting in the middle of the carriage are a little smaller than that in both end, and those sitting in the middle carriage are smaller than in the end carriages.

Keywords track line; bridge; vehicle; passengers; vibration

Fault Diagnosis of Rolling Bearing Using Optimal WPE-Based ANVTPSO-BPNN

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Abstract In order to improve the efficiency and accuracy of fault diagnosis, a fault diagnosis method of rolling bearing of the adaptive no velocity term particle swarm optimization-back propagation neural network (ANVTPSO-BPNN) with optimal wavelet packet energy (WPE) is proposed. The wavelet analysis is used to denoise the vibration signal, and the energy feature is extracted by the wavelet packet decomposition. The basis function and decomposition level are optimized. The inertia weight and learning factor of particle swarm optimization (PSO) algorithm are adaptively adjusted, and the speed term of standard PSO is discarded to avoid the influence of particle initial velocity on the convergence speed and solution accuracy. According to the measured data of a certain bearing, five different BPNN algorithms are verified. The results show that the proposed method has only 273 iteration steps and its diagnosis accuracy reaches 99%. Compared with BPNN before and after noise elimination and two PSO-BPNNs after noise elimination, the method has the higher diagnosis efficiency and accuracy.

Keywords rolling bearing; fault diagnosis; wavelet denoising; wavelet packet decomposition; particle swarm optimization; neural network

Motor Fault Diagnosis Based on Improved SAB with Attention Mechanism

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Abstract Due to the complex motor structure and its operating environment, there is a strong nonlinear relationship between different faults and their fault features, the motor diagnosis driven by the single signal cannot satisfy the requirements. Considering this dilemma, a motor fault diagnosis method driven by multi-sensor information based on attention mechanism and SVM-AdaBoost (SAB) is proposed in this study. First, the corresponding frequency features of current and magnet signals are extracted by Hilbert transform and Fourier transform. Then, the SAB classifier is utilized to train multi-source signals and obtain sub-classifier results respectively. Finally, based on attention machanism, an attention weight matrix is adjusted to fuse the information and calculate the final diagnosis results. The proposed method is verified by realizing the diagnosis of broken rotor bar fault, stator short circuit fault and bearing fault. The proposed method reveals that the sensitivity of different signals to various faults is different. Compared with the traditional methods, the proposed method examine its superiority in terms of the robustness, generalization ability and fault diagnosis accuracy.

Keywords induction motor; fault diagnosis; multi-sensors; attention mechanism; support vector machine (SVM); AdaBoost

Load Condition Monitoring of Pin Connection Based on Nonlinear Ultrasonic Theory

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Abstract Aiming at the problem that the traditional linear ultrasonic method is not sensitive to small changes in the interface contact state, the paper proposes a method of monitoring the load state of the pin connection based on the nonlinear ultrasonic theory. Lead zirconate titanate piezoelectric ceramics is installed on the pin shaft and lug plate to transmit and receive ultrasonic signals. Non-linear ultrasonic theory is used to analyze the second harmonic of the received signal to identify the load of the pin shaft connection. The theory of the propagation mechanism of the ultrasonic wave between the pin and the lug is studied, and the relationship between the linear and nonlinear characteristic parameters and the interface pressure is established based on the principle of the contact acoustic nonlinearity of the rough interface. Finally, the theoretical analysis results are verified through the experimental research of the pin connection device. The results show that the linear characteristic parameters cannot identify small changes in the pin connection state, while the nonlinear characteristic parameters based on the second harmonic can identify the changes in the pin connection state under all test load conditions.

Keywords pinned shaft; monitoring; piezoelectric ceramics; nonlinear ultrasound; second harmonic