Self-excited Vibration Control of Planar 3-RRR Flexible Parallel Manipulator Based on Intelligent Controllers

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Abstract The singularity of the planar 3-RRR flexible parallel manipulator is complicated due to the closed-chain coupling effect. The parallel manipulator is easy to occur self-excited vibration near the inverse Jacobian singular configurations, which seriously affects the accuracy of the mechanism and damages its structure. In order to restore the parallel mechanism to normal operation, active vibration controllers are designed to suppress the self-excited vibration. Firstly, the inverse kinematics model of the mechanism is established, and the singularity judgement conditions of the parallel mechanism are obtained based on the velocity Jacobian matrix. On the basis of analyzing the mechanism of self-excited vibration, the vibration acceleration signal is filtered and phase shifted. Combining acceleration feedback and position error compensation, a fuzzy neural network nonlinear controller and BP neural network active disturbance rejection controller are designed. Finally, the effectiveness of the two intelligent controllers is verified by conducting active vibration control experiments. The experimental results show that the two control algorithms can quickly and effectively suppress the self-excited vibration while ensuring the positioning accuracy of the parallel manipulator.

Keywords parallel manipulator; self-excited vibration; vibration control; fuzzy neural network; active disturbance rejection control

Elastic Modal Matching Method for Double-Stage Vibration Isolation System of Powertrain

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Abstract This paper proposes a flexible structure energy decoupling method based on generalized elastic force work, to obtain elastic vibration coupling frequency band diagram. The coupling degree of elastic vibration mode is evaluated for matching their elastic modal design. A double-stage vibration isolation system of powertrain is studied. Firstly, a multi-degree-of-freedom dynamics model of a double-stage vibration isolation system is established considering the elastic modes. Then the flexible decoupling energy decoupling method is used to quantify the vibration coupling degree between the power pack and the intermediate frame elastic modes. The coupling band width curves at different elastic frequencies are obtained. The results show that the anti-phase vibration between vibration modes can mutually reduce the modal equivalent mass, in-phase vibration modes can increase the modal equivalent mass, thus changing the national characteristics of the system because of the coupling essence between elastic modes. Based on the elastic vibration coupling band curve, the avoided coupling band width between the powertrain and intermediate frame elastic mode frequencies can be determined to follow the instructions of the vibration isolation system. The elastic mode matching method between the powertrain and intermediate frame can be accomplished. The vibration performance test demonstrates that the method can effectively control the elastic vibration coupling degree between the powertrain and the intermediate frame with good vibration isolation performance. Therefore, the method can provide a theoretical support for similar problems and reference for the elastic modal matching of similar models.

Keywords diesel railcar; powertrain system; flexible double-stage vibration isolation system; elastic mode matching; design method

Comparison of Vibration Characteristics in Over-Track Buildings with Different Structural Types

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Abstract The comprehensive development of urban over-track areas is promoting the intensive progress of metropolises, and thus there are numerous buildings with different structural types increasingly emerging above the metro depots in these cities. However, the interaction between subway vehicles and tracks may induce vibrations to affect the comfort in over-track buildings. It is necessary to perform a comparative study of vibration characteristics in over-track buildings with different structural types. The research subjects of this paper are the steel frame and reinforced concrete frame buildings in the Shanghai Xujing metro depot. Field tests are carried out in these two buildings with different structural types. Comparisons of vibration responses are performed using evaluation indexes including the Z vibration level, one-third octave plumb vibration level, total root-mean-square acceleration, etc. The results show that the vibration responses of the first story in these buildings are almost the same, while the responses of the mid and top stories of the steel building are larger than those of the reinforced concrete building. There are high-frequency (100～180 Hz) vibrations existing in the reinforced concrete building. Besides, their vibration responses meet the limits of different codes. To further improve the floor comfort of over-track steel buildings, the design thickness of the mid and top stories can be appropriately increased. This study can provide data support for the development of over-track buildings with different structural types.

Keywords over-track buildings; structural types; field tests; vibration characteristics; vibration evaluation

Dynamic Detection Method of Wheel Polygon Wear Based on Parametric Power Spectrum Estimation

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Abstract Due to the inherent defects of traditional spectrum estimation methods, it is difficult to accurately identify the abnormal wear signal of the wheel, especially for the identification of the initial wheel polygonal wear. To solve the above problem, a dynamic detection method of wheel polygon is proposed based on parametric power spectrum estimation. Firstly, the harmonic frequency recovery model is established according to the dynamic characteristics of the wheel polygon. Secondly, the order of the harmonic recovery model is determined in terms of the singular value decomposition method and normalized error analysis. Thirdly, the total least square method is used to calculate the parameters of the harmonic recovery model. Finally, the power spectrum of the abnormal wear signal is estimated according to Cadzow's estimation theory. Taking the measured signal of axle box vertical vibration acceleration of a subway vehicle as an analysis case, the feasibility and correctness of this method are verified. The results show that this method can realize high-precision frequency-domain estimation based on short-time sequence data, which is sensitive to harmonic signals, especially suitable for identifying initial wheel polygon abnormal wear.

Keywords railway vehicle; wheel polygon; dynamic detection; estimate; power spectrum; parametric

Vortex-Induced Vibration of Free Hanging Segmented Flexible Riser

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Abstract The vortex-induced vibration experiment of a free-hanging segmented riser is carried out in a towing pool. The dynamic response of the segmented riser is studied by changing the speed of the trailer to drag the riser to generate different flow velocities. The riser strain response, dominant frequency, displacement response and other parameters are analyzed based on the modal analysis method, and the dynamic response law of typical pipe sections is discussed. Then the mechanism of vortex-induced vibration of free-hanging segmented riser is explored. The results indicate that the free-hanging riser undergoes different degrees of torsion under the influence of vortex-induced vibration. The greater the reduced velocity means the stronger the influence degree, and the effect of drag force on the vibration response of a free-hanging riser cannot be ignored in the cross-flow direction. The middle and lower positions of the riser show obvious modal competition under the effect of vortex-induced vibration. At low reduced velocities which are different from the conventional boundary conditions (hinged at both ends or fixed at both ends), the dominant frequencies of the vortex-induced vibration of the riser are doubled in the two directions, which are consistents. The change trend of the displacement amplitude in the cross-flow direction of the riser is opposite to the in-line direction, and the modal conversion range lags in the in-line direction behind the cross-flow direction, resulting in modal conversion not occurring in the same reduced velocity range.

Keywords free hanging; segmented; flexible riser; vortex-induced vibration; dynamic response

Methodology of Reference Sensor Placement for Active Control of Road Noise Inside Vehicle

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Abstract Due to the reasonable placement of reference sensors being crucial for road noise cancellation (RNC) systems, a reference sensor placement method is proposed based on multiple coherence analysis (MCA). The model of reference sensor placement is established according to MCA combined with multi-channel normalized filter-x least mean square (NFxLMS) algorithm, and the location with the maximum multiple coherence coefficient is selected. In order to improve the accuracy of multiple coherence calculation, truncated singular value decomposition is used, and genetic algorithm is employed to optimize the multiple coherence analysis results. The simulation and experiment of RNC are carried out on an electric vehicle, and the results demonstrate that the proposed reference sensor placement method can improve the noise reduction of RNC system.

Keywords road noise cancellation; reference signal; multiple coherence; genetic algorithm

Constant Speed Ratio Controlled Synchronization of a Vibrating System with Two-Motor Drives

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Abstract Aiming at the problem that the same frequency excitation vibration system is not conducive to screen-

ing diverse materials and the vibration system with different frequency cannot realize synchronous motion with arbitrary constant speed ratio, a constant speed ratio controlled synchronization method of double excitation vibration system is proposed. The dynamic equation of the vibration system driven by two reverse rotating machines is established by using Lagrange equation, and the response equations of the constant speed ratio of the vibration system are deduced. The fuzzy proportional-integral-derivative (PID) controlled method is designed by using Matlab/Simulink, and the constant speed ratio controller is designed based on the master-slave control mode, so that the two excitation reverse drive constant speed ratio vibration system can control the synchronous motion. The constant speed ratio parameters selected in this paper are 1.2 and 1.5, respectively. The simulation results show that the vibration synchronization of vibration system cannot achieve the given constant speed ratio, but the controlled synchronization can be achieved. The effectiveness of constant speed ratio controlled by synchronization theory for two excitation driven vibration system is verified by experiments.

Keywords controlled synchronization; fixed frequency ratio synchronization; vibration system; master-slave control; fuzzy PID control

The Influence of System Parameters on the Frequency of Vertical Wheel-Rail Coupled System

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Abstract The characteristics of wheel-rail coupled vibration are of great significance to the design of vehicle system and the matching of vehicle and track. Therefore, based on the modal superposition method and eigenvalue algorithm, this paper proposes a method to calculate the natural frequencies of the coupled wheel-rail system and analyzes the influence of the system parameters on the vibration characteristics of coupled wheel-rail system. Results show that pin-pin resonance in the track system is easy to be found when the rail is discretely supported, while there is no obvious pin-pin resonance phenomenon when the rail is continuously supported. The pin-pin resonance frequency is proportional to the bending stiffness of the rail and inversely proportional to the vibration mass of track and the span of the fastener. The wheel-rail resonance is the coupled vibration of the wheelset and the rail on the elastic foundation of track, in which the frequency is significantly lower than the natural frequency of the track. The system parameters have a greater influence on the wheel-rail resonance frequency, and it increases with the mass of the wheelset and decrease with the equivalent stiffness of the fastener. The wheel/rail resonance frequency increase obviously, once the frequency-dependent stiffness of fastener is considered. The short-wave irregularity will induce wheel-rail resonance and worsen the wheel-rail interaction. Tested results reveal that the resonance speed is 23～68 km/h when the wavelength vary from 100 to 300 mm.

Keywords vehicle; track; wheel-rail resonance; pin-pin resonance; modal superposition; track irregularity

Design of Reflective Optical Fiber Oil Contamination Detection Sensor

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Abstract In view of the fact that 70% of the faults of hydraulic equipment caused by oil contamination, solid particles are the main contamination. Most of the commonly used oil contamination detection technology and

equipment have the status of complex structure, expensive price and inconvenient online detection. Herein, a reflective optical fiber oil contamination detection sensor is designed. According to the attenuation of light intensity caused by the blocking of light by contamination particles, combined with the propagation characteristics of light in liquid, the working principle of oil contamination degree reflective optical fiber detection is proposed. The mathematical model of the sensor is established according to the approximate Gaussian distribution of the optical field at the end of the optical fiber. The influence of different parameters on the output characteristics of the sensor is analyzed. The structure of the sensor probe is determined. The reflective optical fiber sensor for oil contamination detection is designed. Based on the sensor test platform, the standard oil is configured according to different contamination levels to verify the characteristics of the sensor. Experimental results show that the sensor can detect the hydraulic contaminated oil with different contamination level standards.

Keywords reflective optical fiber; oil contamination; sensor; mathematical model; output characteristics

Impact Feature Extraction Based on the Adaptive Variable Scale Morphological Filter

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Abstract Faults of reciprocating compressor are observed as impacts in the vibration signal, but their information such as number and location within a period is difficult to identify because of the severe background noise. Therefore, this paper presents an innovative approach to extract impact features from the vibration signal based on combining ensemble empirical mode decomposition (EEMD) method with an adaptive variable scale morphological filter (AVSMF). The method can extract impact components without previous fault information. Since it is difficult to accurately locate the impact components in a signal, an adaptive impact positioning algorithm is proposed. After smoothing the Hilbert envelope of the signal filtered with Teager energy operator, the location of the impacts can be determined. Repeated simulation experiments are carried out 50 times on impact signals with different frequencies and amplitudes. The results show that the algorithm has high accuracy, precise and stability. The effectiveness and accuracy of the proposed algorithm for early fault diagnosis is also verified by impact detection of the low pressure cylinder mid-body acceleration signal of a flash gas double-acting reciprocating compressor.

Keyword impact feature extraction; morphological filter; reciprocating compressor; fault diagnosis

Research on Remaining Useful Life Prediction of Rolling Bearings Based on Fusion Feature and Model-Data-Fusion

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Abstract Due to the interference of random noise and the degradation characteristics of rolling bearings, tradi-

tional model-data-fusion based remaining useful life (RUL) prediction method of rolling bearings might be affected. Thus, a novel RUL prediction method is proposed based on the fusion indictor and model-data-fusion to improve the accuracy of RUL prediction of rolling bearings. First, the principle component analysis and exponentially weighted moving average algorithm are used to fuse the multiple charactering features for constructing a monotonous fusion indictor. Then, a determining scheme for the first predicting time is built on 3σ criteria to trigger the RUL prediction process, which can avoid the invalidity of the prediction process. Lastly, the Rauch-Tung-Striebel smooth filter algorithm is embedded into the prediction model to reduce the random fluctuation and achieve the reliable RUL of rolling bearing. Simulated and experimental cases demonstrate the effectiveness of the proposed method and its superiority over the traditional model-data-fusion RUL prediction method.

Keywords remaining useful life prediction; model-data-fusion; rolling bearings; fusion feature; smooth filtering

Steam Turbine Bearing Oil Film Instability Fault Diagnosis Based on SSWPT

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Abstract Aiming at the shortcomings of the existing time-frequency analysis methods in the diagnosis of rotor oil film instability faults, synchro-squeezed wave packet transform (SSWPT) is proposed to analyze the non-smooth multi-component signals during the operation of the steam turbine. By selecting different main frequency wavelets for different kinds of signals, the signal time-frequency graph is obtained, and the original signal can be reconstructed from the time-frequency graph by the algorithm, and the accuracy of the existing time-frequency method is compared. Taking a 1 000 MW unit of a power plant as the research object, the rotor oil film oscillation fault diagnosis is carried out by using SSWPT method in view of the major vibration problem of shafting during commissioning. Using the on-site turbine diagnosis managment (TDM) system to collect data and carry out wavelet packet transformation to obtain the wavelet transform coefficient and the instantaneous frequency of non-stationary fault signals. Finally, the wavelet packet transform coefficient is compressed under the instantaneous frequency scale. More accurate frequency components are obtained. The results show that the method is superior to the feature extraction of non-stationary signals, and can accurately judge the location and type of faults, which provides a reliable basis for the unit′s later fault processing.

Keywords shaft system vibration; fault diagnosis; non-stationary signal; synchro-squeezed wave packet transform; frequency component

Experimental Study on Vibration Characteristics and Vibration Reduction Effect of Subway Track Before and After Reconstruction

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Abstract Because of the problem that residents along a subway often complain about excessive vibration noise, the conventional fasteners originally used were reconstructed into floating rail fasteners to reduce the im-

pact of vibration and noise. The characteristics of track vibration, vehicle vibration and noise, building vibration and secondary noise are analyzed by measuring the vibration and noise when the train passes through the section before and after reconstruction. As compared with the conventional fastener track before transformation, the root mean square values of the vertical vibration accelerations of the rail, track bed, and tunnel wall of the floating rail fastener track are reduced by 8%, 70.6%, and 71.4% respectively, and the reduction of tunnel wall vibration is the most significant, and the track vibration reduction effect by the tunnel wall vertical vibration is 8.28 dB. The maximum sound pressure level in the bogie area and in the interior is reduced by 3.6% and 3.4%. The average vibration levels of buildings and the secondary radiation noise in the daytime are reduced by 18.4% and 22.0%. The main frequency of vehicle, track and building vibration and secondary noise is highly close to the P2 resonance frequency of the wheel-rail system, which is one of the main reasons for the vehicle, track and building vibration. The research results of this paper provide a greatly important reference for controlling the vibration and noise problems caused by the subway.

Keywords floating rail fastener; track vibration characteristics; vehicle vibration and noise; building vibration; secondary noise

Torsional Vibration Analysis and Verification of Helicopter Based on State Space Method

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Abstract The mode of the mechanical torsional vibration system of the helicopter is not only easy to couple with the engine fuel conditioning system to produce self-excited vibration, but also resonance occurs when the natural frequency of the mechanical torsional vibration system and the frequency of the rotor excitation force are close to or coincide, so it is very important to calculate the frequency of the mechanical torsional vibration system. In this paper, the dynamic model of helicopter mechanical torsional vibration system is established by using the state space method. The frequency, damping ratio and time constant of a helicopter mechanical torsional vibration system are calculated, and compared with the first-order frequency of torsional vibration at 100% and 75% engine speed measured by the helicopter ground joint test-bed. The error is within the acceptable range of engineering application. The established state space model lays a foundation for the subsequent stability analysis combined with the mathematical model of engine and fuel control system.

Keywords helicopter; torsional vibration; state space; coupling frequency; stability

Indirect Prediction Method of Instantaneous Milling Force Based on Spindle and Feed Axis Currents

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Abstract In this paper, an instantaneous milling force prediction method based on the optimal variable weight method of spindle and feed axis currents is proposed. Firstly, the mapping relationship between the spindle current and the x-direction instantaneous milling force is analyzed, and the delay effect of the current signal is con-

sidered based on the cross-correlation method, then based on the Devavit Hartenberg (DH) method, the kinematic modeling of the five-axis machine tool is carried out, and the driving torque of the feed axis is mapped from the machine tool coordinate system to the tool coordinate system, and the relationship between the driving torque of the feed axis and the instantaneous milling force is obtained based on the force Jacobian matrix. Finally, based on the optimal variable weight method, the influence of the spindle and feed shaft currents on the instantaneous milling force is comprehensively considered, and the instantaneous milling force prediction experiment is carried out on a five-axis machining center. The prediction error of the instantaneous milling force of the optimal weight method is within 10%, which can effectively predict the instantaneous milling force of the machining process.

Keywords five-axis machine tool; spindle current; feed axis current; optimal variable weight method; instantaneous milling force

Optimization Design and Performance Test of Atmospheric Data Sensor

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Abstract In order to realize the omnidirectional and low speed measurement of helicopter, a novel atmospheric data sensor is designed based on Bernoulli principle. The design of total static pressure sensor is put forward based on orthogonal test. And beyond that, servo mechanism including rotating elements and driving mechanism is designed and optimized to realize pitot tube rotating with air flow. For the offset of pressure output drift of atmospheric data sensor, an online data correction method is proposed. The experimental platform is established. The feasibility of the atmospheric data sensor and the veracity of the online data correction method is proved by the experiment data, and the measuring error of the air speed is reduced to less than 2% after online data correction.

Keywords atmospheric data sensors; follow-up mechanism; pressure measurement; error correction

Intelligent Monitoring of Surface Hardness Based on Acoustic Emission in Laser Shock Peening

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Abstract In order to achieve real-time evaluation of the surface microhardness of materials during laser shock peening, an online monitoring method for the surface hardness of 7075 aluminum alloy combining acoustic emission technology and machine learning technology is proposed. Firstly, a comprehensive metric to characterize the surface hardening of material, i.e. the sub-surface hardening rate, is constructed through offline hardness testing; secondly, the anti-symmetric A_0 mode-based Mel cepstrum time-frequency map feature extraction is implemented using modal acoustic emission theory; then, a neural network quality assessment model incorporating multiple sensory fields and attention mechanisms is established; finally, the validity and feasibility of the proposed method are verified by the measured data of laser shock peening. The experimental results show that the proposed time-frequency map features are richer in detail information, and the proposed model achieves the highest average accuracy of 97.41% compared with the traditional neural network.

Keywords laser shock peening; acoustic emission; surface quality monitoring; cepstrum analysis; neural network

Starting Noise Test and Control Method of Automobile Air Conditioning Compressor

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Abstract Aiming at the problem of starting noise in rotary vane compressor, a compressor system is tested, analyzed and improved. Firstly, the noise test platform is built for the test of the rotary vane compressor starting noise in a semi-anechoic chamber, and the starting mechanism of the compressor is analyzed; Then, measures to control the starting noise duration are proposed, and the control effects of different globe valves and clutch structures on the starting noise of the compressor are tested respectively; Finally, the control effect of different globe valves and clutch structure is verified by experiment on a real car. The result shows that the starting noise of rotary vane compressor is an inevitable inherent characteristic; Through the control method of compressor ball valve structure and clutch structure, the starting noise duration can be effectively shortened by 1～2 s.

Keywords rotary vane compressor; starting noise; test method; noise control; automobile air conditioning

Arrangement and Application of Crane Vibration Monitoring Sensors Based on HGSA

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Abstract In order to solve the problems of missing sensor placement methods, low search efficiency of placement points, and inaccurate measurement points in crane monitoring, a vibration sensor placement method based on the harmony genetic search algorithm (HGSA) is proposed. Firstly, establish a model for modal analysis is established to obtain the displacement matrices of each order and establish the optimal parameter combination through parameter comparison. Secondly, a random search mechanism is used to quickly search the displacement matrix to obtain preliminary solutions. Then, the optimal solution is obtained through repeated genetic and mutation iterations of the initial solution. Finally, taking the Gantry crane test device as the object, the modal data analysis system is used to compare the sensor layout schemes obtained by HGSA, harmony search (HS) and genetic algorithm (GA). The results indicate that the peak value of the frequency response function obtained by HGSA is larger, which can more effectively reflect the vibration response of the structure. This method provides a new method for installing vibration monitoring sensors in lifting machinery.

Keywords crane; health monitoring; sensor arrangement; modal analysis; intelligent algorithms

A Structural Damage Information Quantitative Enhancement Method Based on Mahalanobis Distance and EMD

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Abstract Early micro-damage and environmental noise makes it difficult to extract and identify damage information from monitoring data. In this study, a quantitative enhancement method of structural damage information is proposed based on Mahalanobis distance and empirical mode decomposition (EMD). Firstly, structural health monitoring data are decomposed by EMD to obtain multi-order intrinsic mode function (IMF), and the damage sensitive components are extracted by the energy variation of IMF. Secondly, the piecewise Mahalanobis distance cumulant (MDC) is used as the evaluation index of damage information quantitative enhancement, and the accumulative stop criterion is established according to the area of its probability density function. Finally, the applicability and effectiveness of the proposed method in structural damage information extraction and quantitative improvement are verified by numerical simulation and model test data. The results show that the energy transfer of each order IMF is obvious after the occurrence of structural damage. Selecting the IMF with more transfer energy than its own energy and the multi-order IMF with positive relative energy change rate as the damage sensitive component can achieve better damage identification than the original signal. The area change of MDC value probability density function can be used as the cumulative stop criterion to realize the effective identification of minimal damage.

Keywords structural health monitoring; damage identification; Mahalanobis distance; empirical mode decomposition

Application of Dynamic Vibration Absorber in NVH Control of Vehicle Suspension System

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Abstract In order to reduce vehicle interior noise and improve ride comfort, a method of reducing interior noise by using dynamic vibration absorber is carried out. The noise of the rear seats exceeded the acceptable range of passengers during the development of a SUV model. After noise testing and subjective evaluation combined with operational deflection shape (ODS)analysis, the subframe has a large resonance coupling with the vehicle body in the frequency range of 200～300 Hz. Aiming at the existing problems, a scheme of adding a damped dynamic vibration absorber to the subframe is proposed, and a mathematical model of the vibration absorber is established. Moreover, the natural frequency of the vibration absorber is tested to select a suitable vibration absorber. The vibration transfer function (VTF) test of the subframe is carried out to determine the installation position of the vibration absorber, and finally the actual test is executed to verify the effectiveness of the scheme. The research results show that after the optimization by adding vibration absorber to the subframe, the peak noise of the rear seats at 212 Hz can be reduced by 4 dB and the noise at 232 Hz can be reduced by 6 dB. Meanwhile, it can be reduced by an average of 3 dB in the frequency range of 200～250 Hz, which can achieve good noise reduction effect. This application scheme can provide an engineering solution for the control

of vehicle vibration and noise.

Keywords vehicle interior noise; suspension system; operational deflection shape; dynamic vibration absorber; vibration transfer function; noise reduction

Study on Dynamic Excitation Identification method of Components Based on Strain Measurements

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Abstract A dynamic load identification method based on structural strain response is proposed. The research first conducts a theoretical analysis of structural dynamic response and derive the strain expression of structural dynamic response. And the dynamic excitation identification method is then constructed based on the strain response of structure. To improve the accuracy and efficiency of dynamic load identification, the number and orientation of strain gauges is optimized based on the D-optimal algorithm. Finally, taking the dynamic load identification of square cantilever thin plates and automotive trailing arms as examples, the identification of sinusoidal and random loads is carried out respectively. The error sources of the excitation identification are analyzed. Results show that the square thin plate excitation is in good agreement with the original excitation, and the waveform of the trailing arm excitation is basically consistent with the original signal.

Keywords stain response; load identification; stain acquisition; D-optimal optimization algorithm

Vibration Suppression Trajectory Planning Method for Mobile Manipulators Based on MACSF

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Abstract To meet the operation requirements of mobile manipulators with high precision and low-jitter, a novel vibration suppression method for trajectory planning based on the modified asymmetry combined sine function (MACSF) is proposed. Firstly, aiming at the problems of acceleration mutation and instability in the start-stop phase of the traditional asymmetry combined sine function (ACSF), and taking the continuous smoothing of driving function and acceleration as the goal, the acceleration stage and deceleration stage in acceleration time window are designed by using improved combined sine function to reduce joint torque fluctuation of mobile manipulators. Secondly, the linear combination method is used to find the universal driving function satisfying the constraint conditions. Finally, an algorithm verification platform for mobile manipulators is built based on robot operating system (ROS), and a series of experiments are carried out in prototype scenarios using this platform. The experimental results show that the MACSF method can effectively suppress the transient vibration and residual vibration of mobile manipulators, and the inhibition amplitude is within 1mm, which verifies the effectiveness and practicability of the method.

Keywords mobile manipulators; asymmetry combined sine function; trajectory planning; vibration suppression; robot operating system

Synchronous Shaft System Monitoring and Torque Prediction Method of Ship Lift

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Abstract Aiming at the issues of torque value monitoring and variation trend prediction in the process of ship lift synchronous shaft movement, a non-contact measuring method based on strain sensor is designed for achieving synchronous shaft torque real-time and on-line monitoring. Then on the basis of historical monitoring data, the direct-current component of torque signal with variational mode decomposition algorithm is extracted, in order to reduce the amount of torque prediction calculation and make the torque prediction model more suitable for practical working condition. Aiming at the issue of indistinguishable starting point and inconsistent monitoring timing sequence of the synchronous shaft movement process, related fuzzy entropy detection method is proposed. Moreover, by adopting long short-term memory (LSTM) algorithm, the prediction model of synchronous shaft torque is established. Furthermore, the prediction model is verified by comparing with real historical monitoring data. The result shows that using fuzzy entropy to detect the starting point can ameliorate the temporal difference of each sample, and then the accuracy of the prediction model is improved effectively. For all torque monitoring points, the prediction accuracy can be improved by at least 27.5% compared with the foundational threshold judgment prediction method. And at the gearbox connection places, which are the most complex mechanical structure and working conditions of synchronous shaft system, the accuracy of torque prediction is improved by at least 42.9%. So the prediction model can truly predict the variation of synchronous shaft torque. The whole research has a good engineering application value.

Keywords synchronous shaft system; torque prediction; variational mode decomposition; fuzzy entropy; long short-term memory networks

Dynamic Response of High-Speed Train Braking Systems Considering Vehicle Vibration

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Abstract In order to study the influence of vehicle vibration on the temperature and vibration characteristics of the braking system of high-speed trains, a model of the whole vehicle dynamics of high-speed trains was established and verified by field experimental tests. Then a thermal-mechanical coupling finite element model of the disc-block braking system is developed, and it is verified by comparing the temperature distribution of the interface of the simulated and tested friction blocks. Finally, based on the vibration environment obtained from the vehicle dynamics model, the temperature and vibration characteristics of the braking system under the effect of simple harmonic excitation and track irregularity excitation are systematically investigated. The results show that the root mean square value of the vibration acceleration of the braking system increases by 304% and 24%, respectively, with the effects of harmonic excitation frequency was 20 times the rotational frequency and track irregularity compared to the results without external excitations. Besides, the external excitation causes a complex local contact behavior of the system, resulting in a difference in the temperature maximum at the friction block interface and in the temperature field distribution compared to the case without external excitation. Therefore, it is necessary to consider the influence of the vehicle vibration environment when analyzing and evaluating the temperature and vibration characteristics of high-speed train braking systems, especially under continuous long ramp braking conditions.

Keywords high-speed train; braking system; dynamics; thermal-mechanical coupling; track irregularity

Calculation Theory and Performance Analysis on Crack Width of Seismic-damaged RC Columns

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Abstract Crack width can directly represent the damage characteristics of structural components, and it is an important index for seismic damage assessment. In view of the many shortcomings in the calculation methods and measurement of crack width, considering a variety of influence factors, a calculation method of diagonal crack width based on the bond-slip theory is proposed. In view of the uncertain load and the unaccurate calculation of crack width of the member in service, the calculation method and flow chart of transverse crack and oblique crack width of reinforced concrete (RC) column based on bending deformation and shear deformation are presented. On this basis, considering the real state of the RC column under the axial-flexure-shear interaction in earthquake, the theoretical relationship between the displacement and the crack width is established, and the method and process of calculating the maximum crack width according to the total horizontal displacement is proposed. The experimental results show that the maximum crack width of the RC column calculated by the proposed method is accurate and can reveal the dynamic evolution process of the crack width with the increase of displacement under the state of axial-flexure-shear interaction. In addition, the failure mode of RC column can be judged according to the numerical ratio of transverse crack and oblique crack.

Keywords crack width; diagonal crack; transverse crack; reinforced concrete column; earthquake damage assessment; axial-flexure-shear interaction

Research on Deep Convolutional Generative Adversarial Networks Diagnosis Method of Bearing Fault Under Small Sample Condition

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Abstract Industrial faults are rare and sporadic, so the number of fault database samples is generally insufficient. The condition of small sample fault database can easily cause problems such as over-fitting in traditional deep learning, which affects the accuracy of diagnosis. In order to increase the sample size, obtain the fault information, and improve the accuracy of fault diagnosis under the condition of small sample fault database, a method based on deep convolutional generative adversarial networks(DCGAN) is proposed. The checkerboard problem of traditional algorithm is improved through combining the traditional DCGAN algorithm with the nearest neighbor interpolation up-sampling and convolution(USCONV layer). After feature extraction and training of three-channel wavelet images, the model output realistically generated images. The model can accurately expand and enrich the sample set under the condition of small samples fault database, alleviate over fitting and other problems, and improve accuracy of diagnosis. The results show that the USCONV layer can significantly improve the checkerboard problem. In addition, the test accuracy of the diagnosis model for the test set containing various fault conditions before and after the expansion of small-sample-database is increased from 91.67% to 98.96%, which demonstrate the method is feasible and effective.

Keywords fault diagnosis; small sample; deep convolutional generative adversarial networks (DCGAN); deep learning; rolling bearing