High-Precise Measurement and Intelligence Evaluation of Engineering Dynamic Signal

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Abstract For precise calculation in engineering dynamic testing, the correct method of basic parameters is firstly discussed, including frequency, amplitude, phase and damping. Then the dynamic feature improvement method of dynamic range, frequency response and calculus is studied. Finally the comprehensive system modeling method is introduced for high-precise dynamic signal measurement. For signal identification and evaluation base on artificial intelligence, the combination method of feature extraction and deep learning is discussed, and several methods are introduced including sample enhance, transfer learning and self-encode learning, in order to solve the problem of few or no negative samples in engineering.

Keywords dynamic testing; precise measurement; signal processing; deep learning

Vibration Characteristics of Motor Stator in Permanent Magnet Transmission System of Shearer

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Abstract In order to reduce the stator vibration in the permanent magnet drive system of shearer, a permanent magnet synchronous motor (PMSM) model considering cogging effect is established combined with motor vector control based on flux linkage model. The electromechanical coupling dynamic model is simulated including PMSM, gear transmission system and cutting drum load characteristics, and the radial flux density of air gap permanent magnet and armature current are obtained. On this basis, the electromagnetic force, magnetostrictive force, vibration displacement and resonance point are analyzed. The results show that the maximum magnetostrictive force reaches 23.8% of the electromagnetic force, and the resonance phenomenon caused by the excitation frequency of $18f_m$ appears at the motor speed of 393 r/min, when the stator is the silicon steel core. On the contrary, when the stator is the amorphous alloy core, the magnetostrictive force is significantly increased compared with the silicon steel core, and the maximum value reaches 58.5% of the electromagnetic force. Further, when the motor speed is 288 or 433 r/min, there is a resonance caused by the excitation frequency of $18f_m$ or $12f_m$. This phenomenon should be paid attention to in actual use.

Keywords shearer cutting section; permanent magnet synchronous motor (PMSM); stator vibration; magnetostriction; resonance

Wind Tunnel Test on Wind Pressure Distribution of a Super Long-Span Roof

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Abstract In order to study the wind pressure distribution characteristics of Shenzhen International Convention and Exhibition Center with a span of 1.7 km, a wind tunnel pressure test is carried out by using the sectional model method, and the interference effects between different exhibition halls are also considered. For the observation extreme value method based on mutual information, the envelope values of the minimum independent observation time interval of different models are used as the sample independent observation time interval for simplification. The results show that, the extreme wind pressure estimation results of the simplified method and the observation extreme value method based on strict mutual information have good consistency and statistical stability, and the calculation efficiency is greatly improved. Further, the wind pressure distribution characteristics of the whole roof show the rationality of the sectional model method, and the sectional model method can describe the local area of the roof corner in more detail. So, the local wind pressure distribution characteristics of the roof can be obtained more accurately. The sectional model method can accurately reflect the mutual interference between roofs in different exhibition areas. Moreover, the maximum extreme negative pressure interference coefficient of wind sensitive positions between exhibition halls can reach 1.26, and the minimum negative pressure of the whole roof structure can reach −7.0 kPa. The high negative pressure mainly occurs in the corner area of the whole roof. Therefore, sufficient attention should be paid to the high negative pressure corner area in the wind resistance design.

Keywords super large span roof; wind tunnel test; extreme wind pressure estimation; wind pressure distribution; sectional model

Spacecraft Micro-vibration Signal Processing Method Based on Symplectic Geometry Hilbert Transform

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Abstract Symplectic geometry Hilbert transform (SGHT) is proposed to improve current methods for spacecraft micro-vibration signal process. This proposed method is based on symplectic geometry mode decomposition (SGMD) and Hilbert spectrum analysis (HSA). Firstly, the eigenvalues of Hamilton matrix are solved by symplectic geometry similarity transformation and the single component signal can be reconstructed by corresponding eigenvectors. Then, by calculating normalized mutual information, similar components are merged into Symplectic geometry component (SGC) and the input signal is subtracted from the calculated SGC component to obtain a new input signal for the next round of iteration until the termination condition is satisfied. Fi-

nally, Hilbert transform is performed on each SGC to calculate the Hilbert marginal spectrum. The simulation results show that, the proposed SGHT method has better decomposition performance and processing ability under the non-stationary complex micro-vibration signal, compared with the common micro-vibration signal processing methods. Using SGHT method to process the advanced space-based solar observatory (ASO-S) / full-disk vector magneto graph (FMG) ground micro-vibration test signals, SGC components can be identified and the estimated angular displacement envelope is less than 0.015", showing practical engineering significance for satellite and payload development.

Keywords spacecraft; micro-vibration; Symplectic geometry; Hilbert; marginal spectrum

Preliminary Study on Vibration Suppression of Blisk with Slitting

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Abstract The utilization of the blisk in an aero engine offers the possibility of further reducing the weight and the complexity of an engine, but it also incurs vibration problems caused by insufficient damping. This paper proposes a damping enhancement method based on a blisk with slitting and supplemented with different fillers. This damping mechanism is achieved by the inelastic collision energy loss and the filler material damping loss during the vibration. A simplified model is established for a blisk with slitting and filler. Both numerical simulations and experimental tests are carried out. The instantaneous frequency and instantaneous damping ratio of the blisk are identified using the Hilbert Transform. The results indicate that the proposed method can indeed improve the damping for the blisk.

Keywords blisk; slitting; collision vibration reduction; damping; nonlinear parameter identification

The Inspection of Kelly Bars by Ultrasonic Guided Waves

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Abstract Using traditional ultrasonic method to inspect kelly bars with the length up to ten meters is extremely time-consuming and inefficient. In order to solve this problem, the use of ultrasonic guided waves for the inspection of kelly bars is proposed. Firstly, the dispersion curves of kelly bars are derived by using semi-analytical finite element method. The dispersion curve of $L(0,2)$ mode at the frequency range from around 70 kHz to 130 kHz is relative flat and it has highest group velocity values. $L(0,2)$ mode is thus selected as the ultrasonic guided wave inspection mode. Secondly, the center excitation frequency is optimized and selected as 100 kHz. A ring of piezoelectric transducers with the size of 25 mm $\times$5 mm $\times$0.5 mm is selected to improve the signal-to-noise-ratio of $L(0,2)$ mode at the center frequency of 100 kHz. Lastly, $L(0,2)$ mode ultrasonic guided waves is applied to inspect kelly bars by numerical and experimental methods. The results show that $L(0,2)$ ultrasonic guided wave is capable of detecting circular through-hole damages located in the plane and near the edge in a kelly bar. Furthermore, the slot damage near the edge of a kelly bar can also be detected. The inspection efficiency is dramatically improved. Therefore, the use of longitudinal $L(0,2)$ mode ultrasonic guided wave provides a promising and effective alternative for the detection of defects in kelly bars.

Keywords guided waves; kelly bars; semi-analytical finite element method; dispersion curves

Parameters Characteristics of Axial Inductive Displacement Sensors with Constant Flux for Magnetic Bearings

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Abstract Axial inductive displacement sensors with constant flux for magnetic bearings can effectively resist the interference of external magnetic field, but its sensitivity is low. In order to improve its sensitivity, the relationship between the sensitivity and mechanical and electrical parameters is derived according to the new topology and measurement principle of the sensor. The methods are given to improve the sensitivity. Theoretical and experimental results show that the smaller the balance air gap is, the higher the sensitivity of the sensor is, and the sensitivity is approximately and inversely proportional to the size of the air gap. Moreover, the higher the excitation frequency and the apparent power consumed by excitation coils of the sensor, the higher the sensitivity is, and the sensitivity is proportional to their square root. Therefore, the sensitivity of the sensor can be improved by reducing the air gap, increasing the excitation frequency, and increasing the apparent power of the sensor. Based on this, the parameter design methods are proposed to maximize the sensitivity of the sensor within the output capacity of power amplifiers.

Keywords magnetic bearing; inductive sensor; sensitivity; constant flux; anti-interference

Vibration Level Computation Based on Least Squares Discrete State Space System

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Abstract It is an essential step to weigh the acceleration signal in the process of vibration level calculation. The most common weighting method is to use the band-pass digital filters to extract the acceleration data in the corresponding frequency range, and then multiply them by the corresponding weighting factors. Under appropriate filtering parameters, this method has a high computational accuracy but low computational efficiency. Therefore, a method based on least squares state space system is proposed to calculate weighted acceleration. Firstly, the least square algorithm is used to transform the transfer function of the principal weightings into the discrete state space of a single-input-single-output system. Then, the original acceleration signal is taken as the input of the discrete system, and the output signal of the system is the weighted acceleration. Finally, a simulation and a practical test case are applied to validate the accuracy and efficiency of the proposed method. The results show that the new method has a better precision and effectiveness.

Keywords least squares; state space; weighted acceleration; vibration level; environmental vibration

Test and Verification Method of Inertance Based on Virtual-Real Mapping Model

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Abstract To obtain the inertance of actual inerter and verify the dynamic model, inertance test experiments are

carried out based on a ball-screw inerter, and low-frequency harmonic forces are used as the input. The results show that the inertance of the ball-screw inerter is nearly ideal, but it can be easily influenced by the pre-tightening force. Too large or too small pre-tightening force means improper installation, which can make the experimental inertance deviate from the theoretical value. To make sure proper pre-tightening force and facilitate the maintenance of inerter, a virtual-real mapping model of inerter is established, and experiments are carried out. The experiments show that the model can apparently distinguish the pre-tightening force. Furthermore, the model can provide guidance for adjusting the pre-tightening force and the maintenance of inerter in use.

Keywords inerter; inertance; ball-screw inerter; virtual-real mapping model; pre-tightening force

Imbalanced Learning of Fault Data Combined with Cloud Model and Ensemble Classification

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Abstract In order to solve the misclassification problem caused by the imbalance of fault data set, this paper proposes a sample regeneration method based on the forward and backward cloud generation algorithms of Gaussian cloud model. For the category with fewer samples, the eigenvalues of the existing samples are used as the input of the backward cloud algorithm, and the expected E_x, entropy E_n and hyper entropy H_e of the cloud model are calculated. With E_x, E_n and H_e as the input of the forward cloud generation algorithm, cloud droplets (x_i, y_i) whose data volume is larger than the original sample can be derived. Values x of several cloud droplets are collected as new sample eigenvalues, which can supplement the class with a small number of samples and solve the problem of imbalance in terms of data. With the help of ensemble extreme learning machine (E-ELM), the supplementary balanced data set is classified and learned, and the final classification accuracy is improved at the level of algorithm. Finally, the validity of the proposed framework is verified on a rolling bearing fault data set.

Keywords rolling bearing; classification; imbalanced learning; ensemble learning

Research on Condition Recognition Method Based on DK-SVDD for In-wheel Motor Bearing

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Abstract In order to further improve the efficiency and reliability of electric vehicle in-wheel motor bearing condition recognition technology, a condition recognition method based on double kernel based support vector data description (DK-SVDD) is proposed. Aiming at the lower recognition rate of SVDD caused by the mixed data structure, the DK kernel is constructed by combining the radial basis function (RBF) kernel function and the difference of Gaussians (DOG) kernel function with a certain proportion weight. According to the optimal binary tree principle, the condition recognition classifier is designed layer by layer, and the DK-SVDD in-wheel motor bearing condition recognition model is built. At the same time, the particle swarm optimization algorithm is used to optimize the model parameters to improve the learning ability and generalization ability of DK-SVDD. Based on the bench test data of in-wheel motor bearing, the feasibility of the proposed method is verified. The results show that the average training time of DK-SVDD method is 0.065 5 s and the average condition recognition rate is 97.06%. Secondly, compared with RBF or DOG kernel function, DK-SVDD method can effectively improve

the condition recognition rate and reduce the training time under various working conditions. According to the above results, the validity and superiority of proposed method based on DK-SVDD are verified. Obtained results can provide reference for the subsequent development of in-wheel motor bearing state identification to improve the safety and reliability of electric vehicles.

Keywords in-wheel motor bearing; support vector data description; double kernel; double kernel based support vector data description; condition recognition

Simulation of Two Damping Mechanisms of Cantilever Beam with Active Constrained Layer Damping

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Abstract A cantilever beam with partially coated active constrained layer damping (ACLD) is taken as the object to study the simulation methods of two vibration reduction mechanisms involved in the vibration control technology. Firstly, by analyzing the force and deformation of the ACLD structure, the two vibration damping mechanisms of the viscoelastic layer and the piezoelectric layer's anti-phase retardation included in the ACLD vibration damping are described. Then, the viscoelastic shear deformation is expressed in the shape function and the piezoelectric retardative force is deduced by combining the piezoelectric equation and mechanical formula. The dynamic model of the ACLD treated composite beam with two kinds of damping mechanism iss established. Finally, an experimental study is carried out, and the simulation analysis results are verified through the ACLD cantilever beam vibration reduction experimental system. At the same time, the time-domain response of the composite beam when only a single damping mechanism including passive constrained damping or piezoelectric reversed phase blocking mechanism and ACLD processing is compared and analyzed. The results show that the maximum deviation between the simulation and experimental values is 18.6%, proving the rationality of the dynamic analysis model which contains two kinds of vibration damping mechanisms. Active constrained layer damping contains two kinds of damping mechanisms at the same time, so its damping effect is better than the other two vibration control methods which only contain a single damping mechanism.

Keywords active constrained layer damping; cantilever beam structure; dynamics modeling; vibration response analysis; the mechanism of vibration reduction

Dynamic Characteristics of Spindle System Considering the Joint Surface Under Milling Conditions

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Abstract The dynamic characteristics of the machine tool spindle system directly affect the milling stability and surface machining quality, while they are different between static or idle state n milling. The dynamic coupling model of the spindle system and the joint surface under the milling condition is established in this paper, and then the dynamic characteristics of the spindle system under the milling condition is obtained. It is verified by the experimental test of dynamic characteristics of machine tool spindle system during milling. Compared with the

static state, the error of prediction results under milling conditions are reduced by 11.35% on average. It is concluded that radial milling load and rotational speed reduces the stiffness characteristics and system dynamic characteristics of the joint surface, while axial milling load enhances the stiffness characteristics and system dynamic characteristics. The most obvious influence is determined by the spindle rotational speed, followed by radial milling load and then axial milling load. The results provide theoretical support for the prediction of dynamic characteristics and milling stability of spindle system under different milling conditions.

Keywords spindle system; joint surface; dynamic characteristics; milling conditions

Deformation Monitoring of Observation Point Group Considering Individual Difference Effect for High Arch Dams

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Abstract The hydraulic-seasonal-time (HST) model has several shortcomings in the deformation monitoring of high arch dams. Regarding observation point groups with similar deformation characteristics as objects, a new modeling method is developed in this research. First, the hydraulic pressure, seasonal and time panel models are constructed according to panel data structure. Second, the fixed effect (FE) and random effect (RE) are introduced to characterize individual difference effect, and the HST-FE/RE panel model is established. Third, the construction method of confidence ellipsoid is investigated. Using the principle of typical small probability, the deformation monitoring criteria of observation point group are proposed. Finally, a case study is conducted to test the feasibility and effectiveness of the proposed methodology. The multiple correlation coefficients and residual standard deviations of the HST-FE/RE are 99.875% and 0.016 34, respectively. The fitting performance of HST-FE/RE is better than that of HST. The change process of relative error of the HST-FE/RE is stable, and the maximum value is 3.28%. The HST-FE/RE has a higher prediction accuracy than the HST. The confidence ellipsoid criteria compared with the confidence interval criteria has stricter identification conditions for typical small probability deformations. Compared with conventional method, the performance of the proposed methodology is improved, which is more suitable to monitor the deformation behavior of high arch dams.

Keywords deformation monitoring; observation point group; individual difference effect; fixed effect; random effect; confidence ellipsoid

Effect of Inclination Angle on Aerodynamic Characteristics of Single Column Steel Bridge Tower with Variable Cross-Section

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Abstract Compared with the vertical bridge tower with constant cross-section, the three-dimensional effect of inclined one with variable cross-section is more complex. Taking a single column inclined steel bridge tower as

the engineering background, the aerodynamic force coefficients and Strouhal numbers of the bridge tower at different incidence angles α and inclination angles β are measured by wind tunnel test of the rigid model of the entire bridge tower. The effect of the inclination angle on the aerodynamic characteristics of the pylon is analyzed. The results show that at approximately $\alpha=0^\circ$ (inclined direction of the bridge tower flow) and $\alpha=30^\circ$, the inclination weakens the aerodynamic force on the upper sections of the bridge and enhances it on the lower sections. At approximately $\alpha=140^\circ$and $\alpha=180^\circ$ (opposite inclined direction of the bridge tower flow), the opposite rule is observed. The increase of inclination angle makes the vortex shedding of the bridge tower gradually become inconspicuous.

Keywords steel bridge tower; wind tunnel test; inclination angle; aerodynamic coefficient; Strouhal number; three-dimensional effect

The Early Weak Fault Recognition of the Rolling Bearing Under Low Signal to Noise Ratio

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Abstract The early weak fault recognition of the rolling bearing under low signal to noise ratio is always a difficulty problem. The envelope spectrum method based on Hilbert transform demodulation is a classical bearing fault detecting method which is applied on engineering practice widely. However, the method is hard to deal with the early weak fault diagnosis of the bearing. Thus a high-order statistic called spectral kurtosis is used to study the early weak fault recognition of the rolling bearing. The whole life cycle data from rolling bearing run-to-failure test is used for analysis and evaluation. The obtained result shows that the spectral kurtosis method can recognize the early weak fault successfully, and detect the fault in 200 minutes in advance compared to the envelope spectrum method. The advantage of recognizing the weak signal locating in the resonance band with high signal to noise ratio is therefore demonstrated.

Keywords rolling bearing; spectral kurtosis; early weak fault; the whole life cycle

Design of Variable Stiffness Soft Actuator Driven by Shape Memory Alloy

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Abstract The soft gripper exhibits high adaptability when grasping a target. In order to achieve the lightweight design while ensuring capacity of grasping and carrying, the shape memory alloy (SMA) wire is utilized as the actuation source in the paper. The phase transformation characteristics of shape memory alloys are applied to perform the variable stiffness task of a soft actuator. The one-dimensional constitutive model of the shape memory alloy is established to construct the theoretical model of the bending angle of the actuator. In addition, the deformation test for shape memory alloy is carried out. Obtained results show that the theoretical model can reflect the actual bended angle. Moreover, when the SMA wire for variable stiffness is heated, the load-bearing capacity of the actuator is notably improved.

Keywords shape memory alloy; variable stiffness; constitutive model; soft actuator

Improvement Method of Vehicle Floor Vibration Based on Transfer Path Analysis Method

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Abstract Floor vibration is a classic vibration phenomenon during the running process of vehicle. In this paper, the excitation source which cause floor vibration is identified by experimental method. The contribution of each transfer path between the powertrain and the vehicle floor to the vibration is analyzed by extended condition transfer path analysis method. Furthermore, the main paths and important components causing vibration are identified. A dynamic model with 12 degrees of freedom is established. The dynamic response of the model and reaction force of bushing is calculated. The stiffness of bushing is optimized for reducing the floor vibration based on the calculated results of reaction force. Floor vibration are measured for the baseline bushing and the improved bushing. The results show that floor vibration is mainly caused by the rigid body mode of subframe. The peak value of vibration is decreased by more than 30 % after the stiffness optimization of the bushing.

Keywords transfer path analysis; floor vibration; dynamic model; system optimized; extended condition transfer path analysis

Failure Analysis and Optimization of Dust Cover of Brake Disc Under Multi-axis Random Vibration

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Abstract Aiming at the premature failure of a certain type of commercial vehicle brake dust cover, the combination of numerical simulation and experimental verification based on the measured load spectrum is used to identify the failure cause accurately, and an optimization and improvement scheme for life improvement is proposed. Firstly, the micro-morphology of the failure part of the dust cover is analyzed to determine the failure mechanism. Then combined with modal analysis of dust cover structure and random vibration stress response analysis based on measured road load spectrum, the failure cause of structure is identified. Considering the multi-axis coupling characteristics of random loads, the single-axis high acceleration test load spectrum is developed by analyzing the failure dominant load, and the accuracy of simulation analysis results is verified by acceleration test. Finally, the life improvement scheme of dust cover is given by shape optimization, and verified by numerical simulation. The results show that the numerical simulation based on the measured load spectrum is in good agreement with the failure analysis of the dust cover structure by the high acceleration test under the dominant load, and is consistent with the durability test results. The service life of dust cover after shape optimization is significantly improved. This method can provide a reference for structural failure analysis and optimization under multi-axis random vibration load.

Keyword failure analysis; random vibration; high acceleration experiment; shape optimization

Lamb Wave Based Crack Damage Quantitative Imaging Method for Metal Material Structure

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Abstract Ring piezoelectric array and active Lamb wave reconstruction algorithm for probabilistic inspection of damage (RAPID) imaging is introduced to study the metal structure crack damage quantitative monitoring. Based on the mechanism that direct wave signal specifically responses to different damage, the difference of crack damage to the response signal changes under the orthogonal monitoring path, a cross scanning method is proposed to determine the damage direction, and then adjust the signal difference coefficient (SDC) value of damage with parallelly-passing or approximately parallelly-passing path. The proposed method constructs image information of reinforced damage orientation, then realize the image reconstruction and quantitative evaluation of crack damage. Experimental verification is carried out on the aluminum plate, aiming at the monitoring and imaging of cracks in different positions and directions. The experiment results indicate that the proposed cross scanning method and the improved RAPID imaging method can better identify the crack direction and can quantitatively display the crack length.

Keywords crack damage; circular array; Lamb wave; quantitative monitoring; cross orthogonal scan

Transmissibility Characteristics of Geometrically Nonlinear Viscous Damping Vibration Isolation System

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Abstract Aiming at the contradiction between suppressing resonance peaks and improving high-frequency transmission characteristics in traditional shipborne nonlinear vibration isolation systems. First, a mathematical model of the nonlinear vibration isolation system containing the nonlinear stiffness, Coulomb damping and geometric nonlinear viscous damping is established, and the harmonic balance method is used to solve the problem analytically. Then, the influence of linear damping, Coulomb damping and geometric nonlinear damping on the transmission characteristics of vibration isolation system is compared and analyzed, and the influence of excitation amplitude on the vibration performance of different damping vibration isolation system is further studied. Finally, the vibration test is used to verify. The results show that increasing the Coulomb damping of the system can reduce the transmission rate of the soft vibration isolation system in the resonance zone, but the phenomenon of "frequency island" appears in the hard vibration isolation system, and the high-frequency vibration isolation performance decreases at the same time. Moreover, as the excitation amplitude increases, the vibration isolation performance of the resonance zone becomes worse; Increasing the geometric nonlinear viscous damping of the system can not only effectively reduce the peak transmission rate in the resonance region, but also ensure good vibration isolation performance in the high frequency region; At the same time, geometric nonlinear viscous damping broadens the system's applicable range of excitation amplitude, and provides an important guidance for the design of nonlinear vibration isolation systems.

Keywords nonlinear vibration isolation; transmissibility; Coulomb damping; geometrically nonlinear viscous damping; vibration test

Dynamic Test on One Structure in Shanxi Hejin Thermal Plant Under Equipment Excitations

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Abstract The torsional vibration, vertical vibration and horizontal vibration of a steel truss-pipe column hybrid structure system of large power plant under equipment excitations are tested by vibrameter. The time domain analysis and self-spectrum analysis of test data are carried out by DASP program, and the finite element simulation results are combined. The key performance indexes such as vibration response, lateral displacement, longitudinal displacement, vertical displacement, deformation, Angle, mode and frequency of the structure are systematically studied. The results show that the vibration response curves of the measuring points at each characteristic position of the structure are different, and the displacement peaks of the same measuring point are not synchronized, which indicates that the vibration performance of the structure is different in the North-South direction and the east-west direction. The vibration displacement of the corner is larger than that of the middle, and the structure has its own deformation and torsion. The low order modes of the structure are close and there is coupling, which indicates that the structure is not suitable for the calculation of seismic action by the base shear method. The relative deformation of the superstructure is smaller than that of the substructure, and the vibration of the A-shaped frame at the top is retracted, which indicates that the mass and stiffness of the structure change abruptly at the A-shaped frame. The calculated results are in good agreement with the experimental results, and the modal analysis results can provide a theoretical basis for the study of structural dynamic response.

Keywords hybrid structure; field test; vibration response; time domain analysis; spectrum analysis; natural vibration behavior

Voice Feature Extraction of Bel Canto Based on Power Spectrum

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Abstract In order to better study the characteristics of bel canto, a method of voice feature extraction of bel canto based on power spectrum is presented. Firstly, the correct and wrong bel canto signals are analyzed by Burg power spectrum estimation. Secondly, the least square method is used to fit the function polynomial where the power spectrum curve is different. Finally, the polynomial coefficients are extracted as features. 400 soprano signals from three bel canto teachers and five beginners in a music college are collected . The results show that there is a big difference between the two signals at 5 kHz and 10 kHz of power spectrum curve, after the feature extraction by the above method, according to the box-plot of the sample, which can be clearly distinguished between correct and wrong voice, the recognition rate can reach 100%. By comparison, if back propagation (BP) neural network is used to recognize power spectrum signal directly, the recognition rate is only 95.23%. The research results provide technical support for the auxiliary training of bel canto from the perspective of vibration theory.

Keywords audio signal; feature extraction; bel canto; soprano; power spectrum

Method of Extracting Torsional Vibration Signal Based on Lateral Vibration Signal in Rotating Machinery

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Abstract Lateral and torsional vibrations are coupled with each other in a rotor system, and the information of torsional vibration is modulated in lateral vibration signals. In view of this, a method of extracting weak torsional vibration signal from lateral vibration signals is proposed in this paper. Specifically, the Hilbert vibration decomposing is firstly applied on the lateral vibration signal to obtain a single-component signal, which is used to extract the phase angle with Hilbert transformation, and then the phase angle is decomposed to extract the torsional vibration signal. After that, the amplitude and frequency of the original torsional vibration signal are obtained. Numerical simulation and experimental results indicate that the method can accurately detect torsional vibration signals, with a high frequency resolution, and the error of extracted torsional frequency in the experiment is merely 0.38%. An industrial scale of centrifugal compressor experimental platform is employed to validate its feasible application in engineering as well. This method can enable an additional monitoring of torsional vibrations for the machines without dedicated torsional vibration testers, providing a convenient way to measure torsional vibrations in engineering.

Keywords torsional vibration test; Hilbert transformation; rotating machinery; vibration decomposing

Optimal Design of Extremity Exoskeleton Elbow Joint Based on Rocker Slider Mechanism

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Abstract Aiming at the limitation of elbow joint movement and poor power assist effect, an upper limb exoskeleton based on rocker slider mechanism is designed. The kinematics model of the upper limb exoskeleton mechanism is established by D-H parameters, and its working space is analyzed. Based on the rocker slider mechanism, the structure of the upper limb exoskeleton is designed, and the mechanical analysis is carried out to provide the basis for cylinder selection. Based on the parametric model established by ADAMS, the elbow joint size of the upper limb exoskeleton is optimized, and the range of motion of the elbow joint is significantly improved after optimization. The strength of key components is checked by ANSYS, and a physical prototype to collect upper limb electromyography signals for assistance performance evaluation is built, which verified that the upper limb exoskeleton mechanism has a good power assist effect.

Keywords upper limb exoskeleton; rocker slider mechanism; scale optimization design; transient structure analysis; elbow flexion test

Broadband Response Design of Sector-Shaped Piezoelectric Array Energy Harvester for Rail Vehicles

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Abstract In order to improve the utilization efficiency of renewable energy for rail vehicle vibration, a design scheme of piezoelectric beam array is proposed. First, based on Euler-Bernoulli′s theory and analysis of its electromechanical coupling characteristics, this paper establishes the distributed parameter electromechanical model of the sector-shaped dual crystal cantilever beam array. Then, ANSYS software is used for finite element analysis for the axle box vibration signal collected by the Shanghai subway train. a multi-dimensional disk array acquisition system with 12 beam elements is proposeed and a vibration test platform for experiments is built. The results show that the mechanical tuning strategy can be adapted to adjust the design parameters of the piezoelectric array. The working frequency points can be generated at three vibration source frequencies of 20.95, 40.45 and 204.19 Hz to achieve broadband matching with the axle box vibration environment, and the first 12 low-frequency resonance widths of the structure can reach 35.68 Hz. The sector-shaped piezoelectric array energy harvester proposed in this paper has a good broadband response and good output performance. It can be dynamically matched according to rail vehicles′ required environmental vibration characteristics and is suitable for improving the output performance of small passive sensors for intelligent monitoring.

Keywords railbound vehicle; PZT piezoelectric ceramic; vibration energy acquisition units; frequency matching; distributed parameter model; finite element simulation

Analysis of Vibration and Secondary Noise Characteristics of Over-Track Building in Double-Deck Depot

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Abstract In order to study the propagation law of vibration along the over-track building and the secondary structure noise problem caused by the operation of subway in double-deck depot, the field test of the throat section and the over-track building of Hengang double-deck depot is introduced. Fourier transform, transfer loss and 1/3 octave band spectrum are used to study the characteristics of vibration source. On this basis, the relationship between structural vibration and indoor secondary structural noise is analyzed by constructing linear fitting function and cross power spectral density function. It is pointed that, due to the rapid attenuation of high-frequency vibration through soil, in the frequency band above 80 Hz, the vibration acceleration level of the first floor load-bearing column in the depot is less than that of the second floor load-bearing column; when the vibration is transmitted to the top floor along the building, the superposition of the incident wave and the reflected wave makes the vibration energy of the top floor increase; the main frequency of the noise pressure of the secondary structure in the building is within100 Hz, and the peak value appears near 40 Hz, and the frequency band of sound easily excited in buildings is estimated to be 40～60 Hz; the contribution of floor vibration radiation noise to indoor secondary structure noise is mainly around 40 Hz. In summary, it is recommended to focus on the response of vibration transmission along the upper building at 40 Hz.

Keywords double-deck depot; throat area; propagation law; secondary structure noise; correlation analysis

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