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CHINESE JOURNAL OF MECHANICAL ENGINEERING

Review

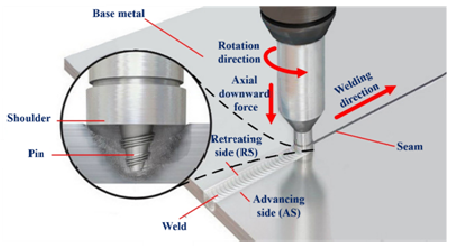
(2020)33:12

DIO: 10.1186/s10033-020-0434-7

Progress in Thermomechanical Analysis of Friction Stir Welding.

Bahman Meyghani • Chuansong Wu

Abstract: This article reviews the status of thermomechanical analysis of the friction stir welding (FSW) process for establishing guidelines for further investigation, filling the available research gaps, and expanding FSW applications. Firstly, the advantages and applications of FSW process are introduced, and the significance and key issues for thermomechanical analysis in FSW are pointed out. Then, solid mechanic and fluid dynamic methods in modeling FSW process are described, and the key issues in modeling FSW are discussed. Different available mesh modeling techniques including the applications, benefits and shortcomings are explained. After that, at different subsections, the thermomechanical analysis in FSW of aluminum alloys and steels are examined and summarized in depth. Finally, the conclusions and summary are presented in order to investigate the lack of knowledge and the possibilities for future study of each method and each material.



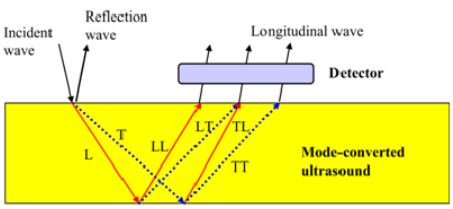
(2020)33:11

DIO: 10.1186/s10033-020-0431-x

Research Review of Principles and Methods for Ultrasonic Measurement of Axial Stress in Bolts.

Qinxue Pan • Ruipeng Pan • Chang Shao • Meile Chang • Xiaoyu Xu

Abstract: Bolts are important fasteners indispensable in the manufacturing field for their advantages, which include convenient assembly and disassembly, easy maintenance, refastenability to prevent looseness, and the avoidance of a phase change in the connected material composition. The precise control of the tightening force in bolts is closely related to the safety and reliability of the connected equipment or structure. Although there are many methods for estimating the tightening force applied to a bolt during assembly, poor accuracy in controlling the preload during the tightening process and a lack of monitoring to determine the residual axial force in service remain issues in evaluating the safety of bolted assemblies. As a nondestructive testing technology, ultrasonic measurement can be applied to successfully address these issues. In order to help researchers understand the theoretical basis and technological development in this field and to equip them to conduct further in-depth research, in this review, the basic knowledge describing the state of stress and deformation of bolts, as well as conventional testing methods are summarized and analyzed. Then, through a review of recent research of the ultrasonic measurement of the axial stress in bolts, the influence of the effective stressed length and temperature are analyzed and proposed methods of calibration and compensation are reviewed. In order to avoid coupling errors caused by traditional piezoelectric transducers, two newly proposed ultrasonic coupling technologies, the electromagnetic acoustic transducer (EMAT) and the permanent mounted transducer system (PMTS), are reviewed. Finally, the new direction of research of the detection of residual axial stress in in-service bolts that have been assembled to yield is discussed.



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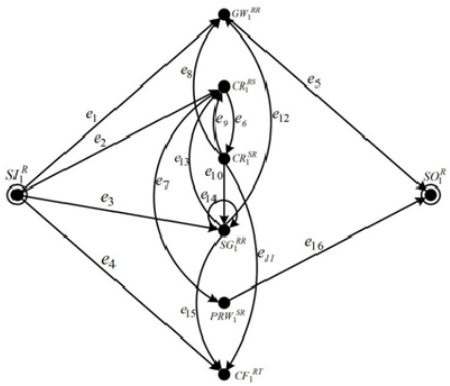
Innovative Design of Complex Products



(2020)33:2
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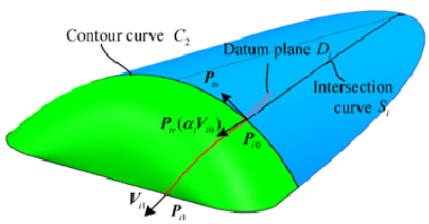
A Computational Synthesis Approach of Mechanical Conceptual Design Based on Graph Theory and Polynomial Operation.

Lin Han • Geng Liu • Xiaohui Yang • Bing Han

Abstract: The design synthesis is the key issue in the mechanical conceptual design to generate the design candidates that meet the design requirements. This paper devotes to propose a novel and computable synthesis approach of mechanisms based on graph theory and polynomial operation. The graph framework of the synthesis approach is built firstly, and it involves: (1) the kinematic function units extracted from mechanisms; (2) the kinematic link graph that transforms the synthesis problem from mechanical domain into graph domain; (3) two graph representations, i.e., walk representation and path representation, of design candidates; (4) a weighted matrix theorem that transforms the synthesis process into polynomial operation. Then, the formulas and algorithm to the polynomial operation are presented. Based on them, the computational flowchart to the synthesis approach is summarized. A design example is used to validate and illustrate the synthesis approach in detail. The proposed synthesis approach is not only supportive to enumerate the design candidates to the conceptual design of a mechanical system exhaustively and automatically, but also helpful to make that enumeration process computable.



(2020)33:4
DOI: 10.1186/s10033-019-0425-8

Smoothing Parametric Design of Addendum Surfaces for Sheet Metal Forming.

Jixing Li • Tao Ning • Ping Xi • Bifu Hu • Tian Wang • Jiong Yang

Abstract: The manual design of addendum surfaces on common CAD platforms is very tedious which requires many trials-corrections, which will certainly affect the construction efficiency and quality of addendum surfaces, and then affect the formability and quality of the workpiece in the process of sheet forming. In this paper, an automatic procedure based on parametric design method is proposed for the rapid construction of the addendum surfaces. The kernel of the parametric method is constructing boundary curves based on the shape of surfaces of workpiece and designing guide curves based on Hermite curve interpolation. By some simple parameters, the shape of the addendum surfaces could be controlled and adjusted easily. In addition, a minimum energy optimization method is employed to further optimize the constructed addendum surface. A finite element analysis for the sheet forming process is performed to evaluate the forming quality of constructed addendum surfaces. The instance illustrates that the addendum surface constructed by the proposed method could ensure both the overall smoothing of surfaces and the final forming quality, and it has a good effect on springback after forming. This research proposes a smoothing parametric design method for addendum surfaces construction which could construct and optimize addendum surfaces rapidly.

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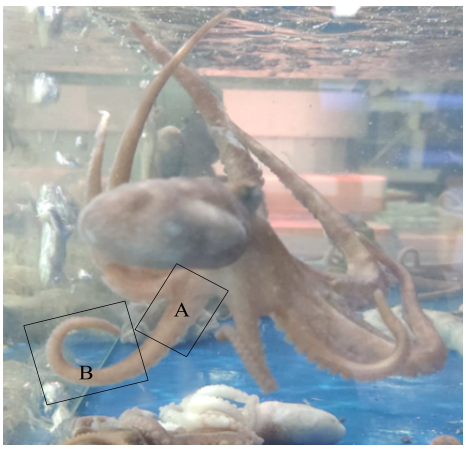
DOI: 10.1186/s10033-019-0426-7

Flexible Bio-tensegrity Manipulator with Multi-degree of Freedom and Variable Structure

Dunwen Wei • Tao Gao • Xiaojuan Mo • Ruru Xi • Cong Zhou

Abstract: Conventional manipulators with rigid structures and stiffness actuators have poor flexibility, limited obstacle avoidance capability, and constrained workspace. Some developed flexible or soft manipulators in recent years have the characteristics of infinite degrees of freedom, high flexibility, environmental adaptability, and extended manipulation capability. However, these existing manipulators still cannot achieve the shrinking motion and independent control of specified segments like the animals, which hinders their applications. In this paper, a flexible bio-tensegrity manipulator, inspired by the longitudinal and transversal muscles of octopus tentacles, was proposed to mimic the shrinking behavior and achieve the variable motion patterns of each segment. Such proposed manipulator uses the elastic spring as the backbone, which is driven by four cables and has one variable structure mechanism in each segment to achieve the independent control of each segment. The variable structure mechanism innovatively contains seven lock-release states to independently control the bending and shrinking motion of each segment. After the kinematic modeling and analysis, one prototype of such bionic flexible manipulator was built and the open-loop control method was proposed. Some proof-of-concept experiments, including the shrinking motion, bending motion, and variable structure motion, were carried out by controlling the length of four cables and changing the lock-release states of the variable structure mechanism, which validate the feasibility and validity of our proposed prototype. Meanwhile, the experimental results show the flexible manipulator can accomplish the bending and shrinking motion with the relative error less than 6.8% through the simple independent control of each segment using the variable structure mechanism. This proposed manipulator has the features of controllable degree-of-freedom in each segment, which extend their environmental adaptability, and manipulation capability.



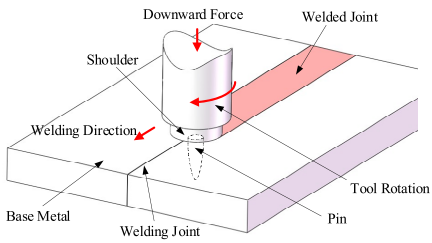
(2020)33:1

DOI: 10.1186/s10033-019-0427-6

Kinematic Sensitivity Analysis and Dimensional Synthesis of a Redundantly Actuated Parallel Robot for Friction Stir Welding

Xinxue Chai • Ningbin Zhang • Leiying He • Qinchuan Li • Wei Ye

Abstract: Friction stir welding (FSW) has been widely applied in many fields as an alternative to traditional fusion welding. Although serial robots can provide the orientation capability required to weld along curved surfaces, they cannot adequately support the huge axial downward forces that FSW generates. Available parallel mechanism architectures, particularly redundantly actuated architectures for FSW, are still very limited. In this paper, a redundantly actuated 2UPR-2RPU parallel robot for FSW is proposed, where U denotes a universal joint, R denotes a revolute joint and P denotes a prismatic pair. First, its semi-symmetric structure is described. Next, inverse kinematics analysis involving an analytical representation of rotational axes is implemented. Velocity analysis is also conducted, which leads to the formation of a Jacobian matrix. Sensitivity performance is evaluated utilizing level set and convex optimization methods, where the local sensitivity indices are unit consistent, coordinate free, and of definite physical significance. Furthermore, global and hierarchical sensitivity indices are proposed for the design process. Finally, dimension synthesis is conducted based on the sensitivity indices and the optimal link parameters of the parallel robot are obtained. In summary, this paper proposes a dimensional synthesis method for a redundantly actuated parallel robot for FSW based on sensitivity indices.



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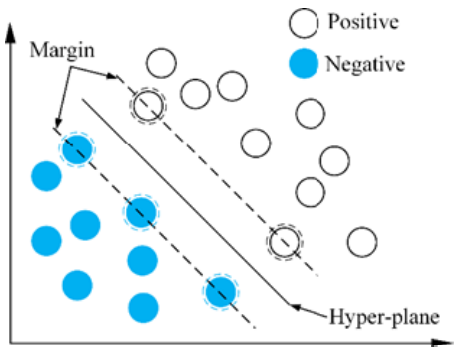
DOI: 10.1186/s10033-019-0428-5

Particle Swarm Optimization-Support Vector Machine Model for Machinery Fault Diagnoses in High-Voltage Circuit Breakers. Xiaofeng Li • Shijing Wu • Xiaoyong Li • Hao Yuan • Deng Zhao

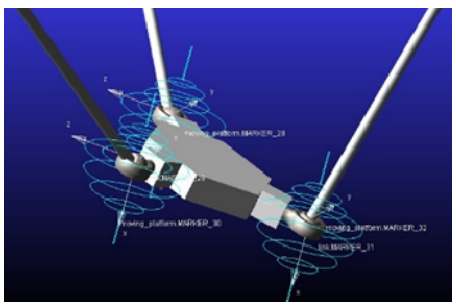


Abstract: According to statistic data, machinery faults contribute to largest proportion of High-voltage circuit breaker failures, and traditional maintenance methods exist some disadvantages for that issue. Therefore, based on the wavelet packet decomposition approach and support vector machines, a new diagnosis model is proposed for such fault diagnoses in this study. The vibration eigenvalue extraction is analyzed through wavelet packet decomposition, and a four-layer support vector machine is constituted as a fault classifier. The Gaussian radial basis function is employed as the kernel function for the classifier. The penalty parameter c and kernel parameter δ of the support vector machine are vital for the diagnostic accuracy, and these parameters must be carefully predetermined. Thus, a particle swarm optimization-support vector machine model is developed in which the optimal parameters c and δ for the support vector machine in each layer are determined by the particle swarm algorithm. The validity of this fault diagnosis model is determined with a real dataset from the operation experiment. Moreover, comparative investigations of fault diagnosis experiments with a normal support vector machine and a particle swarm optimization back-propagation neural network are also implemented. The results indicate that the proposed fault diagnosis model yields better accuracy and efficiency than these other models.

Mechanism and Robotics

(2020)33:13
DOI: 10.1186/s10033-020-0433-8

Kinematic and Dynamic Analysis of a 3-PRUS Spatial Parallel Manipulator. Mervin Joe Thomas • M L Joy • A P Sudheer



Abstract: Parallel Kinematic Machines (PKMs) are being widely used for precise applications to achieve complex motions and variable poses for the end effector tool. PKMs are found in medical, assembly and manufacturing industries where accuracy is necessary. It is often desired to have a compact and simple architecture for the robotic mechanism. In this paper, the kinematic and dynamic analysis of a novel 3-PRUS (P: prismatic joint, R: revolute joint, U: universal joint, S: spherical joint) parallel manipulator with a mobile platform having 6 Degree of Freedom (DoF) is explained. The kinematic equations for the proposed spatial parallel mechanism are formulated using the Modified Denavit-Hartenberg (DH) technique considering both active and passive joints. The kinematic equations are used to derive the Jacobian matrix of the mechanism to identify the singular points within the workspace. A Jacobian based stiffness analysis is done to understand the variations in stiffness for different poses of the mobile platform and further, it is used to decide trajectories for the end effector within the singularity free region. The analytical model of the robot dynamics is presented using the Euler-Lagrangian approach with Lagrangian multipliers to include the system constraints. The gravity and inertial forces of all links are considered in the mathematical model. The analytical results of the dynamic model are compared with ADAMS simulation results for a pre-defined trajectory of the end effector.

(2020)33:17
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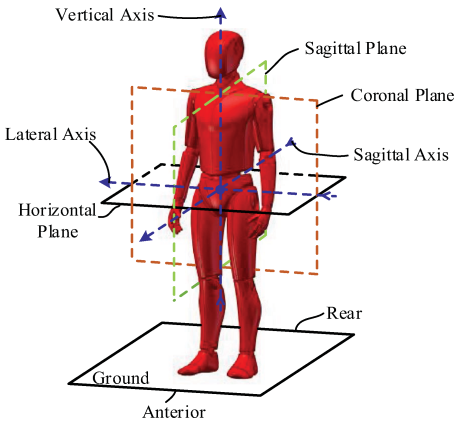
Dynamic Analysis and Performance Verification of a Novel Hip Prosthetic Mechanism. Majun Song • Sheng Guo • Xiangyang Wang • Haibo Qu

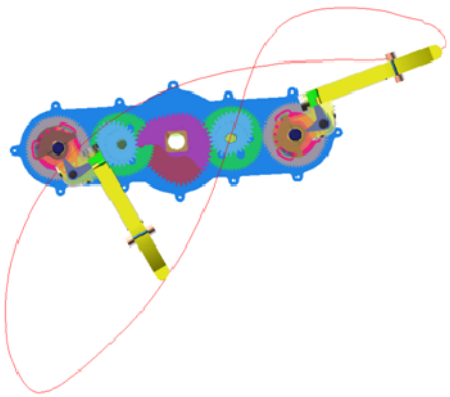
Abstract: To assist an amputee in regaining his or her daily quality of life, based on analysis of the motion characteristics of the human hip, a 2-UPR/URR parallel mechanism with a passive limb was designed. The inverse kinematics of this mechanism was analyzed based on a closed-loop vector method. The constrained Jacobian matrix and kinematic Jacobian matrix of each limb were then analyzed, and a 6×6 fully Jacobian matrix was constructed. Based on this, kinematic performances were analyzed and summarized. Finally, the dynamic model of the mechanism was constructed based on the virtual work principle, and its theoretical solution was compared with the numerical results, which were obtained in a simulation environment. Results showed that the prosthetic mechanism had a larger rotating workspace and better mechanical performance, which accorded a range of motion and bearing capacity similar to that of the human hip in multiple gait modes. Moreover, the validity of the dynamic model and inverse kinematics were verified by comparing the theoretical and simulation results. Furthermore, with flexion and extension, the torque change in the hip prosthetic mechanism was similar to that of the human hip, which demonstrated the feasibility of the hip prosthetic mechanism and its good dynamic performance.



(2020)33:10
DOI: 10.1186/s10033-020-0432-9

Automatic Scallion Seedling Feeding Mechanism with an Asymmetrical High-order Transmission Gear Train.
Xiong Zhao • Jun Ye • Mengyan Chu • Li Dai • Jianneng Chen

Abstract: The current automatic scallion-transplanting machine is a complicated mechanism composed of two linkage mechanisms and two band carriers. It delivers seedlings inefficiently because of the movement limitations of the linkage mechanism. This paper proposes a new high-order non-circular gear train for an automatic scallion-seedling feeding mechanism. The proposed gear train has an asymmetrical transmission ratio; i.e., its transmission ratio varies. This allows the mechanism's execution component to move in a long displacement and rotate in a large rotation angle. The long displacement enables the execution component to reach the designed working position, and the large rotation angle allows it to feed a scallion in the required pose. A mathematical model for calculating the asymmetrical transmission ratio was established according to the closure requirements and the full-cycle motion of the driven gear pitch curve. Then, the parameter-design model of the new seedling-feeding mechanism was established, based on precise pose points and trajectory-shape control points. Moreover, an aided-design program was developed to obtain the parameter-solution domain of the scallion-seedling feeding mechanism. The mechanism parameters, which met the seedling-feeding function, were optimized to determine the transmission ratio, using a program and a kinematic simulation. Finally, a prototype of the mechanism was produced, and a seedling-feeding experiment was carried out. One-thousand seedlings were tested at a rate of 100 seedlings per minute, and the statistical success rate was 93.4%. Thus, the automatic scallion-seedling feeding mechanism significantly improves the efficiency of automatically transplanting scallions.



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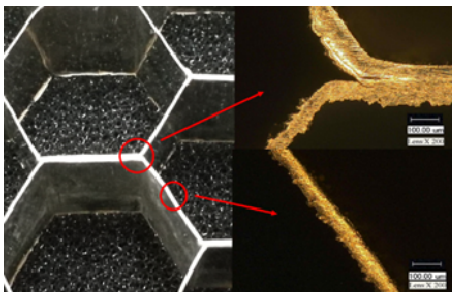
Intelligent Manufacturing Technology

(2020)33:20
DOI: 10.1186/s10033-020-00439-1

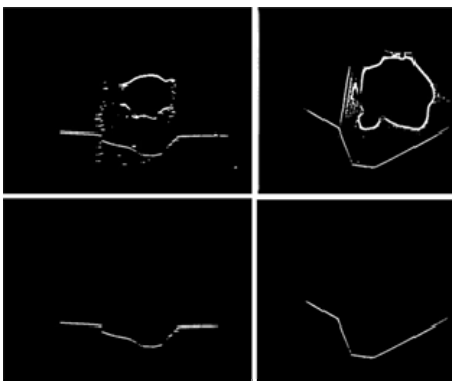
Surface Quality Improvement in Machining an Aluminum Honeycomb by Ice Fixation. Yongqing Wang • Yongquan Gan • Haibo Liu • Lingsheng Han • Jinyu Wang • Kuo Liu



Abstract: A honeycomb structure is widely used in sandwich structure components in aeronautics and astronautics; however, machining is required to reveal some of its features. In honeycomb structures, deficiencies, such as burrs, edge subsiding, and cracking, can easily appear, owing to poor specific stiffness in the radial direction. Some effective fixation methods based on a filling principle have been applied by researchers, including approaches based on wax, polyethylene glycol, iron powder, and (especially) ice. However, few studies have addressed the optimization of the cutting parameters. This study focused on optimizing the cutting parameters to obtain a better surface roughness (calculated as a roughness average or R_a) and surface morphology in the machining of an aluminum alloy honeycomb by an ice fixation method. A Taguchi method and an analysis of variance were used to analyze the effects and contributions of spindle speed, cutting depth, and feed rate. The optimal cutting parameters were determined using the signal-to-noise ratio combined with the surface morphology. An F-value and P-value were calculated for the value of the R_a, according to a "smaller is better" model. Additionally, the optimum cutting parameters for machining the aluminum honeycomb by ice fixation were found at different levels. The results of this study showed that the optimal parameters were a feed rate of 50 mm/min, cutting depth of 1.2 mm, and spindle speed of 4000 r/min. Feed rate was the most significant factor for minimizing R_a and improving the surface morphology, followed by spindle speed. The cutting depth had little effect on R_a and surface morphology. After optimization, the value of R_a could reach 0.218 μm, and no surface morphology deterioration was observed in the verified experiment. Thus, this research proposes optimal parameters based on ice fixation for improving the surface quality.

(2020)33:21
DOI: 10.1186/s10033-020-00438-2

Discerning Weld Seam Profiles from Strong Arc Background for the Robotic Automated Welding Process via Visual Attention Features.
Yinshui He • Zhuohua Yu • Jian Li • Lesheng Yu • Guohong Ma



Abstract: In the robotic welding process with thick steel plates, laser vision sensors are widely used to profile the weld seam to implement automatic seam tracking. The weld seam profile extraction (WSPE) result is a crucial step for identifying the feature points of the extracted profile to guide the welding torch in real time. The visual information processing system may collapse when interference data points in the image survive during the phase of feature point identification, which results in low tracking accuracy and poor welding quality. This paper presents a visual attention feature-based method to extract the weld seam profile (WSP) from the strong arc background using clustering results. First, a binary image is obtained through the preprocessing stage. Second, all data points with a gray value 255 are clustered with the nearest neighborhood clustering algorithm. Third, a strategy is developed to discern one cluster belonging to the WSP from the appointed candidate clusters in each loop, and a scheme is proposed to extract the entire WSP using visual continuity. Compared with the previous methods the proposed method in this paper can extract more useful details of the WSP and has better stability in terms of removing the interference data. Considerable WSPE tests with butt joints and T-joints show the anti-interference ability of the proposed method, which contributes to smoothing the welding process and shows its practical value in robotic automated welding with thick steel plates.

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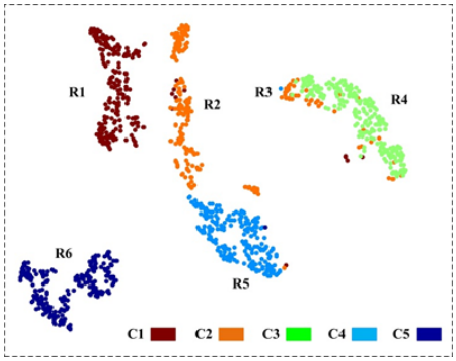
A Fast Multi-tasking Solution: NMF-Theoretic Co-clustering for Gear Fault Diagnosis under Variable Working Conditions.

Fei Shen • Chao Chen • Jiawen Xu • Ruqiang Yan



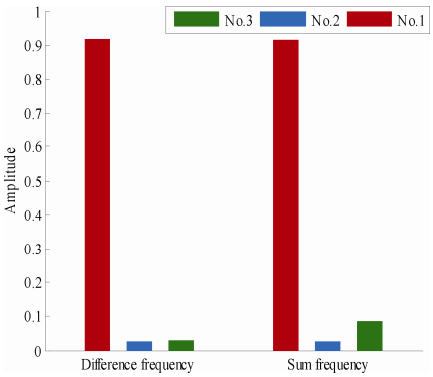
Abstract: Most gear fault diagnosis (GFD) approaches suffer from inefficiency when facing with multiple varying working conditions at the same time. In this paper, a non-negative matrix factorization (NMF)-theoretic co-clustering strategy is proposed specially to classify more than one task at the same time using the high dimension matrix, aiming to offer a fast multi-tasking solution. The short-time Fourier transform (STFT) is first used to obtain the time-frequency features from the gear vibration signal. Then, the optimal clustering numbers are estimated using the Bayesian information criterion (BIC) theory, which possesses the simultaneous assessment capability, compared with traditional validity indexes. Subsequently, the classical/modified NMF-based co-clustering methods are carried out to obtain the classification results in both row and column tasks. Finally, the parameters involved in BIC and NMF algorithms are determined using the gradient ascent (GA) strategy in order to achieve reliable diagnostic results. The Spectra Quest's Drivetrain Dynamics Simulator gear data sets were analyzed to verify the effectiveness of the proposed approach.

(2020)33:9

DOI: 10.1186/s10033-020-0430-y

Application of Uniform Experimental Design in Optimizing Excitation Parameters for Magnetic Frequency Mixing Measurements.

Yu Chang • Jingpin Jiao • Xiucheng Liu • Guanghai Li • Cunfu He • Bin Wu



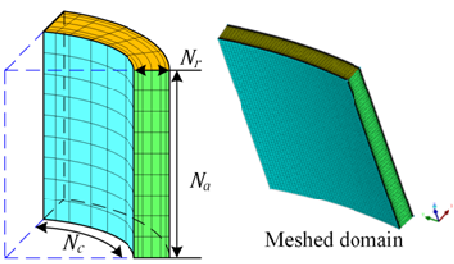
Abstract: Excitation parameter preferences are key factors affecting the performance of magnetic frequency mixing detection. A uniform experimental design method was used to analyze this influence. Using fuzzy theory, a comprehensive model is established for evaluating the effect of magnetic frequency mixing. A polynomial is selected as the regression function to express explicitly the correlation between the excitation parameters and the frequency-mixing effect. The excitation parameters were then optimized using genetic algorithm. Magnetic frequency mixing experiments were conducted to measure the surface hardness of some ferromagnetic materials. Frequency mixing is further enhanced under the optimal settings, resulting in an improvement in the measurement sensitivity. The results of this study support the application of the magnetic frequency mixing technique in non-destructive testing.

(2020)33:14

DOI: 10.1186/s10033-020-0435-6

Flow Resistance Modeling for Coolant Distribution within Canned Motor Cooling Loops.

Shengde Wang • Zhenqiang Yao • Hong Shen



Abstract: Taylor-Couette-Poiseuille (TCP) flow dominates the inner water-cooling circulation of canned motor reactor coolant pumps. Current research on TCP flow focuses on torque behaviors and flow regime transitions through experiments and simulations. However, research on axial flow resistance in a large Reynolds number turbulent state is not sufficient, especially for the various flow patterns. This study is devoted to investigating the influence of annular flow on the axial flow resistance of liquid in the coaxial cylinders of the stator and rotor in canned motor reactor coolant pumps, and predicting the coolant flow distribution between the upper coil cooling loop and lower bearing lubricating loop for safe operation. The axial flow resistance, coupled with the annular rotation, is experimentally investigated at a flow rate with an axial Reynolds number, Re_a, from 2.6×10^3 to 6.0×10^3 and rotational Reynolds number, Re_t, from 1.6×10^4 to 4.0×10^4. It is revealed that the axial flow frictional coefficient varies against the axial flow rate in linear relation sets with logarithmic coordinates, which shift up when the flow has a higher Re_t. Further examination of the axial flow resistance, with the Re_a extending to 3.5×10^5 and Re_t up to 1.6×10^5, by simulation shows gentle variation rates in the axial flow frictional coefficients against the Re_a. The relation curves with different Re_t values converge when the Re_a exceeds 3.5×10^5. A prediction model for TCP flow consisting of a polygonal approximation with logarithmic coordinates is developed to estimate the axial flow resistance against different axial and rotational Reynolds numbers for the evaluation of heat and mass transfer during transition states and the engineering design of the canned motor chamber structure.

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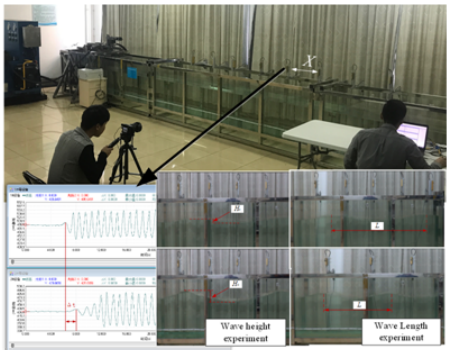

(2020)33:5
DOI: 10.1186/s10033-019-0429-4

Simple Push-Type Wave Generating Method Using Digital Rotary Valve Control. Yi Liu • Jiafei Zheng • Ruiyin Song • Qiaoning Xu • Junhua Chen • Fangping Huang

Abstract: The important parameters to describe waves are their amplitude and length. In order to make it easier to improve wave amplitude and facilitate wave experiment, a simple push-type wave generating method using digital rotary valve control was proposed and different wave amplitudes were generated by the new method. After the mathematical model of the new method had been established, numerical analysis based on the linear wave theory was carried out by means of Matlab/Simulink software tools, and experiments were conducted on the push-type wave maker to ascertain the validity of the established model and the numerical simulation results. It shows that both experimental and theoretical results agree relatively well, and the plate motion frequency and amplitude of the push-type wave maker can be continuously adjusted and the various required regular waves can be obtained. Although the wave amplitude and length descends with the increasing of working frequency, the wave amplitude can be improved conveniently by setting the axial opening width of the valve and the oil supply pressure of system. The wave length remains unchanged with the axial opening width and the oil supply pressure change. The research indicates that different regular waves can be easily generated by the new method and the wave amplitude can be further improved in a certain plate motion frequency range.