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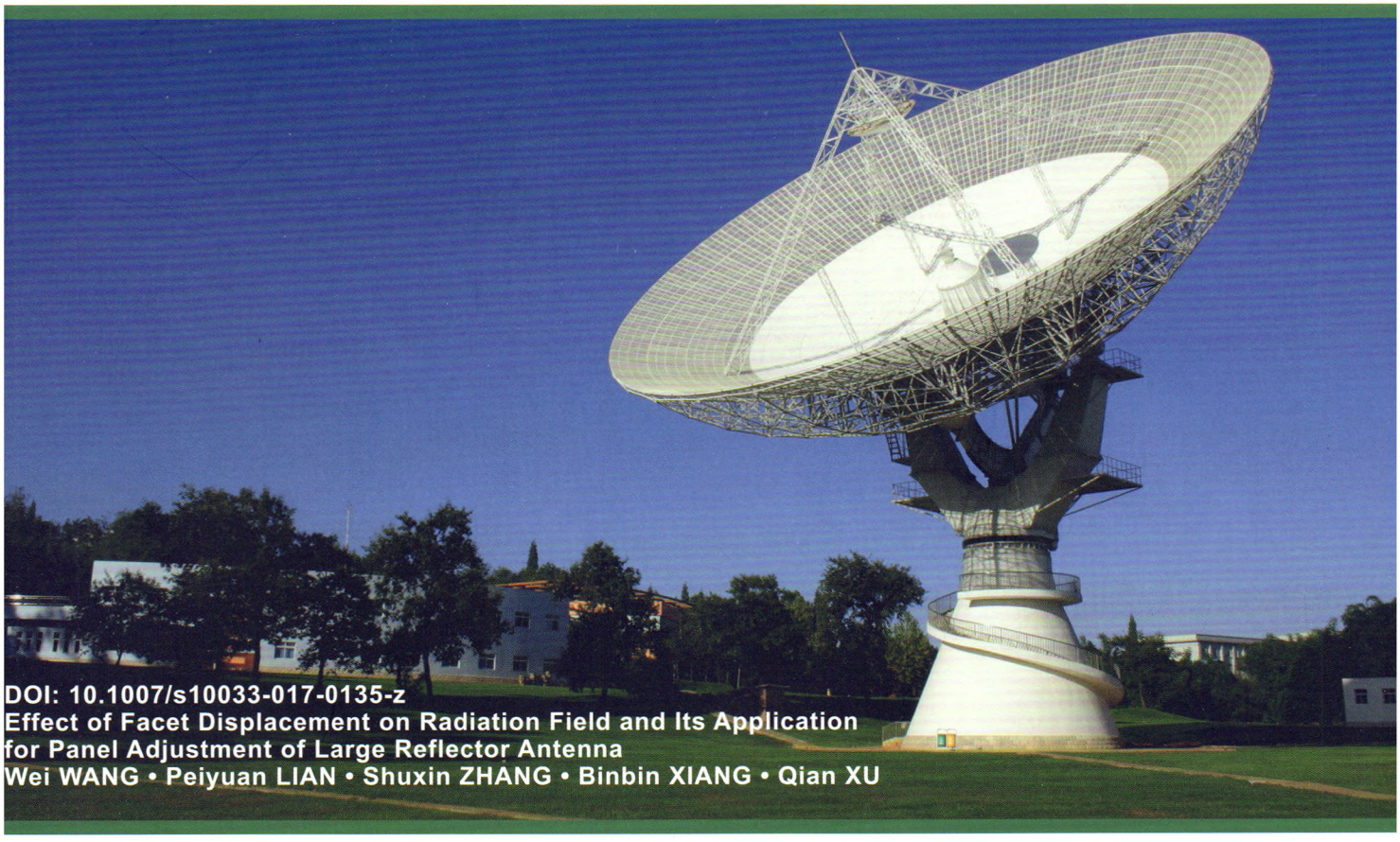

DOI: 10.1007/s10033-017-0135-z

Effect of Facet Displacement on Radiation Field and Its Application for Panel Adjustment of Large Reflector Antenna

Wei WANG • Peiyuan LIAN • Shuxin ZHANG • Binbin XIANG • Qian XU

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May 2017

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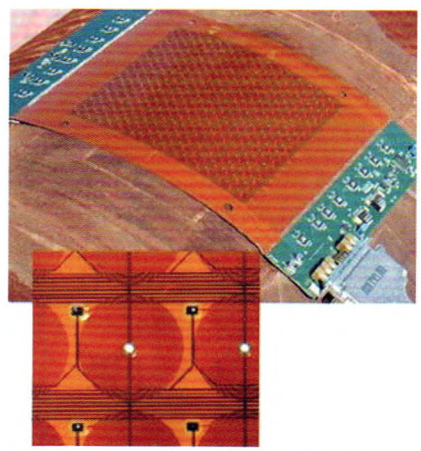
CHINESE JOURNAL OF MECHANICAL ENGINEERING

EDITORIAL

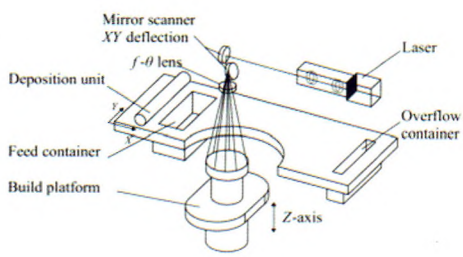
RESEARCH HIGHLIGHT

REVIEW

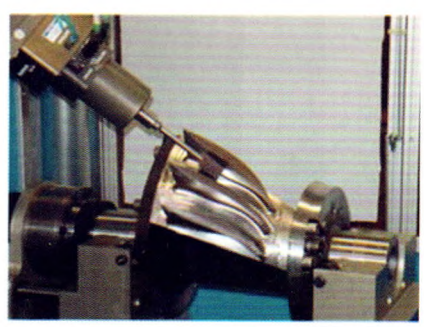
Abstract: Pulsed eddy current (PEC) non-destructive testing and evaluation (NDT&E) has been around for some time and it is still attracting extensive attention from researchers around the globe, which can be witnessed through the reports reviewed in this paper. Thanks to its richness of spectral components, various applications of this technique have been proposed and reported in the literature covering both structural integrity inspection and material characterization in various industrial sectors. To support its development and for better understanding of the phenomena around the transient induced eddy currents, attempts for its modelling both analytically and numerically have been made by researchers around the world. This review is an attempt to capture the state-of-the-art development and applications of PEC, especially in the last 15 years and it is not intended to be exhaustive. Future challenges and opportunities for PEC NDT&E are also presented.



Abstract: Defect formation is a common problem in selective laser melting (SLM). This paper provides a review of defect formation mechanisms in SLM. It summarizes the recent research outcomes on defect findings and classification, analyzes formation mechanisms of the common defects, such as porosities, incomplete fusion holes, and cracks. The paper discusses the effect of the process parameters on defect formation and the impact of defect formation on the mechanical properties of a fabricated part. Based on the discussion, the paper proposes strategies for defect suppression and control in SLM.



Abstract: The integral impeller and blisk of an aero-engine are high performance parts with complex structure and made of difficult-to-cut materials. The blade surfaces of the integral impeller and blisk are functional surfaces for power transmission, and their surface integrity has significant effects on the aerodynamic efficiency and service life of an aero-engine. Thus, it is indispensable to finish and strengthen the blades before use. This paper presents a comprehensive literature review of studies on finishing and strengthening technologies for the impeller and blisk of aero-engines. The review includes independent and integrated finishing and strengthening technologies and discusses advanced rotational abrasive flow machining with back-pressure used for finishing the integral impeller and blisk. A brief assessment of future research problems and directions is also presented.



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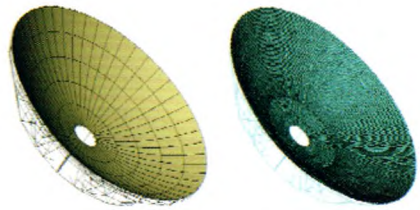
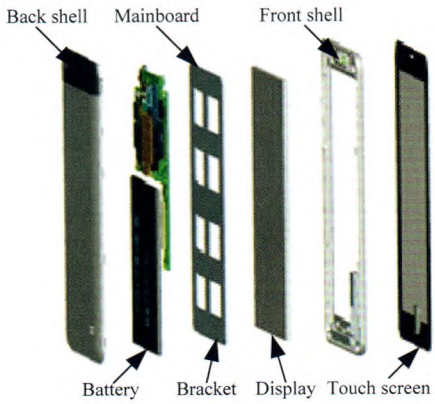
ORIGINAL ARTICLES

Electromechanical Coupling Design for Electronic Equipment



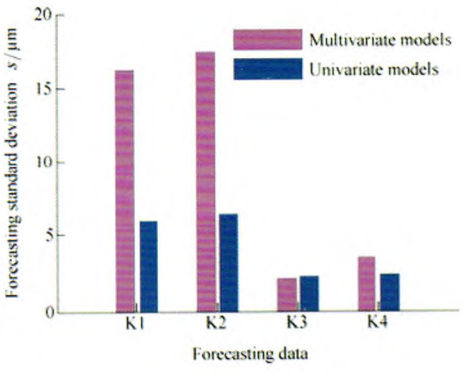
DOI 10.1007/s10033-017-0131-3

Abstract: The construction of traditional finite element geometry (i.e., the meshing procedure) is time consuming and creates geometric errors. The drawbacks can be overcame by the Isogeometric Analysis (IGA), which integrates the computer aided design and structural analysis in a unified way. A new IGA beam element is developed by integrating the displacement field of the element, which is approximated by the NURBS basis, with the internal work formula of Euler-Bernoulli beam theory with the small deformation and elastic assumptions. Two cases of the strong coupling of IGA elements, "beam to beam" and "beam to shell", are also discussed. The maximum relative errors of the deformation in the three directions of cantilever beam benchmark problem between analytical solutions and IGA solutions are less than 0.1%, which illustrate the good performance of the developed IGA beam element. In addition, the application of the developed IGA beam element in the Root Mean Square (RMS) error analysis of reflector antenna surface, which is a kind of typical functional surface whose precision is closely related to the product's performance, indicates that no matter how coarse the discretization is, the IGA method is able to achieve the accurate solution with less degrees of freedom than standard Finite Element Analysis (FEA). The proposed research provides an effective alternative to standard FEA for shape error analysis of functional surface.



DOI 10.1007/s10033-017-0130-4

Abstract: Most of the current evolutionary algorithms for constrained optimization algorithm are low computational efficiency. In order to improve efficiency, an improved differential evolution with shrinking space technique and adaptive trade-off model, named ATMDE, is proposed to solve constrained optimization problems. The proposed ATMDE algorithm employs an improved differential evolution as the search optimizer to generate new offspring individuals into evolutionary population. For the constraints, the adaptive trade-off model as one of the most important constraint-handling techniques is employed to select better individuals to retain into the next population, which could effectively handle multiple constraints. Then the shrinking space technique is designed to shrink the search region according to feedback information in order to improve computational efficiency without losing accuracy. The improved DE algorithm introduces three different mutant strategies to generate different offspring into evolutionary population. Moreover, a new mutant strategy called "DE/rand/best/1" is constructed to generate new individuals according to the feasibility proportion of current population. Finally, the effectiveness of the proposed method is verified by a suite of benchmark functions and practical engineering problems. This research presents a constrained evolutionary algorithm with high efficiency and accuracy for constrained optimization problems.



DOI 10.1007/s10033-017-0109-1

Abstract: Aiming at the deficiency of the robustness of thermal error compensation models of CNC machine tools, the mechanism of improving the models' robustness is studied by regarding the Leaderway-V450 machining center as the object. Through the analysis of actual spindle air cutting experiments data on Leaderway-V450 machine, it is found that the temperature-sensitive points used for modeling is volatility, and this volatility directly leads to large changes on the collinear degree among modeling independent variables. Thus, the forecasting accuracy of multivariate regression model is severely affected, and the forecasting robustness becomes poor too. To overcome this effect, a modeling method of establishing thermal error models by using single temperature variable under the jamming of temperature-sensitive points' volatility is put forward. According to the actual data of thermal error measured in different seasons, it is proved that the single temperature variable model can reduce the loss of forecasting accuracy resulted from the volatility of temperature-sensitive points, especially for the prediction of cross quarter data, the improvement of forecasting accuracy is about 5 μm or more. The purpose that improving the robustness of the thermal error models is realized, which can provide a reference for selecting the modeling independent variable in the application of thermal error compensation of CNC machine tools.

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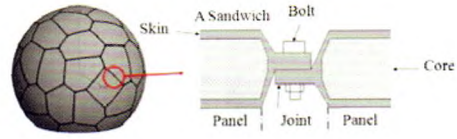
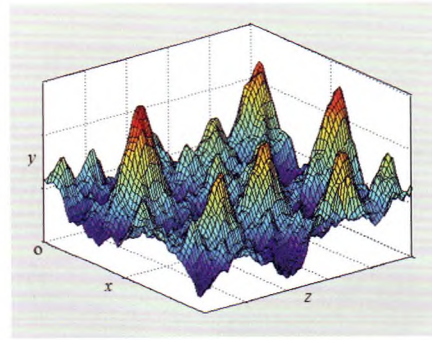
Abstract: Large reflector antennas are widely used in radars, satellite communication, radio astronomy, and so on. The rapid developments in these fields have created demands for development of better performance and higher surface accuracy. However, low accuracy and low efficiency are the common disadvantages for traditional panel alignment and adjustment. In order to improve the surface accuracy of large reflector antenna, a new method is presented to determinate panel adjustment values from far field pattern. Based on the method of Physical Optics (PO), the effect of panel facet displacement on radiation field value is derived. Then the linear system is constructed between panel adjustment vector and far field pattern. Using the method of Singular Value Decomposition (SVD), the adjustment value for all panel adjustors are obtained by solving the linear equations. An experiment is conducted on a 3.7m reflector antenna with 12 segmented panels. The results of simulation and test are similar, which shows that the presented method is feasible. Moreover, the discussion about validation shows that the method can be used for many cases of reflector shape. The proposed research provides the instruction to adjust surface panels efficiently and accurately.



Abstract: Some compensation methods have been proposed to mitigate the degradation of radiation characteristics caused by composite material radomes, however most of them are complex and not applicable for large radomes, for example, the modification of geometric shape by grinding process. A novel and simple compensation strategy based on phase modification is proposed for large reflector antenna-radome systems. Through moving the feed or sub-reflector along axial direction opportunely, the modification of phase distribution in the original aperture of an enclosed reflector antenna can be used to reduce the phase shift caused by composite material radomes. The distortion of far-field pattern can be minimized. The modification formulas are proposed, and the limitation of their application is also discussed. Numerical simulations for a one-piece composite materials sandwich radome and a 40 m multipartite composite materials sandwich radome verify that the novel compensation strategy achieves satisfactory compensated results, and improves the distortion of the far-field pattern for the composite material radomes. For one-piece dielectric radome, more than 60% phase difference caused by radome is reduced. For multipartite radome, the sidelobe level improves about 1.2 dB, the nulling depth improves about 3 dB. The improvement of far-field pattern could be obtained effectively and simply by moving the feed or sub-reflector according to phase shift of the radome.



Abstract: Modeling of the roughness in micro-nano scale and its influence have not been fully investigated, however the roughness will cause amplitude and phase errors of the radiating slot, and decrease the precision and efficiency of the SWA in Ku-band. Firstly, the roughness is simulated using the electromechanical coupled(EC) model. The relationship between roughness and the antenna's radiation properties is obtained. For verification, an antenna prototype is manufactured and tested, and the simulation method is introduced. According to the prototype, a contrasting experiment dealing with the flatness of the radiating plane is conducted to test the simulation method. The advantage of the EC model is validated by comparisons of the EC model and two classical roughness models (sine wave and fractal function), which shows that the EC model gives a more accurate description model for roughness, the maximum error is 13%. The existence of roughness strongly broadens the beamwidth and raises the side-lobe level of SWA, which is 1.2 times greater than the ideal antenna. In addition, effect of the EC model's evaluation indices is investigated, the most affected scale of the roughness is found, which is 1/10 of the working wavelength. The proposed research provides the instruction for antenna designing and manufacturing.

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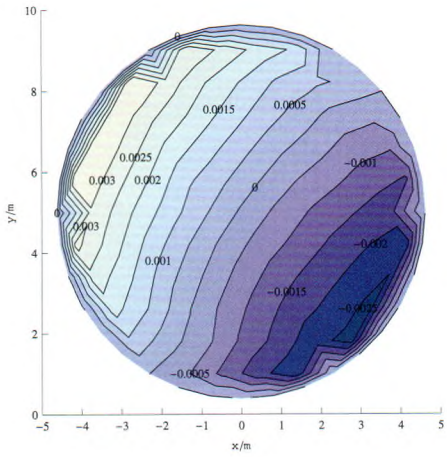
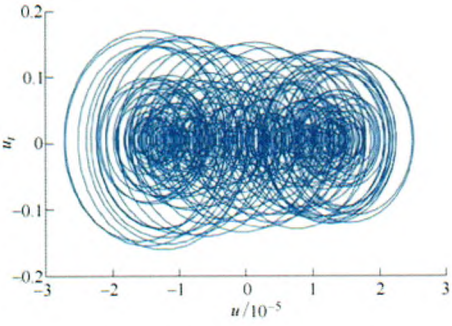


DOI 10.1007/s10033-017-0134-0

Two-step Structural Design of Mesh Antennas for High Beam Pointing Accuracy. Shuxin Zhang • Jingli Du • Wei Wang • Xinghua Zhang • Yali Zong

Abstract: A well-designed reflector surface with high beam pointing accuracy in electromagnetic performance is of practical significance to the space application of cable mesh reflector antennas. As for space requirements, circular polarizations are widely used in spaceborne antennas, which usually lead to a beam shift for offset reflectors and influence the beam pointing accuracy. A two-step structural design procedure is proposed to overcome the beam squint phenomenon for high beam pointing accuracy design of circularly polarized offset cable mesh reflectors. A simple structural optimal design and an integrated structural electromagnetic optimization are combined to alleviate the beam squint effect of circular polarizations. It is implemented by cable pretension design and adjustment to shape the offset cable mesh surface. Besides, in order to increase the efficiency of integrated optimization, an update Broyden-Fletcher-Goldfarb-Shanno(BFGS) Hessian matrix is employed in the optimization iteration with sequential quadratic programming. A circularly polarized offset cable mesh reflector is utilized to show the feasibility and effectiveness of the proposed procedure. A high beam pointing accuracy in order of 0.000 1 ° of electromagnetic performance is achieved.

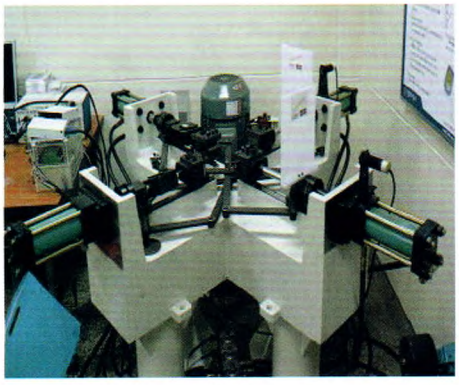
Advanced Manufacturing Technology



DOI 10.1007/s10033-017-0104-6

Roll System and Stock's Multi-parameter Coupling Dynamic Modeling Based on the Shape Control of Steel Strip. Yang Zhang • Yan Peng • Jianliang Sun • Yong Zang

Abstract: The existence of rolling deformation area in the rolling mill system is the main characteristic which distinguishes the other machinery. In order to analyze the dynamic property of roll system's flexural deformation, it is necessary to consider the transverse periodic movement of stock in the rolling deformation area which is caused by the flexural deformation movement of roll system simultaneously. Therefore, the displacement field of roll system and flow of metal in the deformation area is described by kinematic analysis in the dynamic system. Through introducing the lateral displacement function of metal in the deformation area, the dynamic variation of per unit width rolling force can be determined at the same time. Then the coupling law caused by the co-effect of rigid movement and flexural deformation of the system structural elements is determined. Furthermore, a multi-parameter coupling dynamic model of the roll system and stock is established by the principle of virtual work. More explicitly, the coupled motion modal analysis was made for the roll system. Meanwhile, the analytical solutions for the flexural deformation movement's mode shape functions of rolls are discussed. In addition, the dynamic characteristic of the lateral flow of metal in the rolling deformation area has been analyzed at the same time. The establishment of dynamic lateral displacement function of metal in the deformation area makes the foundation for analyzing the coupling law between roll system and rolling deformation area, and provides a theoretical basis for the realization of the dynamic shape control of steel strip.



DOI 10.1007/s10033-017-0128-y

Effect of Plastic Anisotropy on the Formability of Aluminum 6016-T4 Sheet Material. Young-Suk Kim • Seung-Han Yang

Abstract: Sheet metal formed of lightweight materials such as aluminum sheeting has received great attention related to the reduction of vehicle emissions. This paper evaluates the anisotropic yield locus using Kuwabara's biaxial tensile tester and stretches formability using Hecker's hemispherical punch stretching test for aluminum 6016-T4 sheet material. The anisotropic yield locus of the Al6016-T4 sheet measured is fitted well by the modified Drucker yield function. Moreover the best fitting to the experimental stress-strain curve from the tensile test was obtained by taking an appropriate hardening model. Analytical study to predict the stretch formability by using Hora's Modified Maximum Force Criterion (MMFC) was performed. The predicted forming limit curves (FLC) based on various yield functions were compared with the experiments and discussed.

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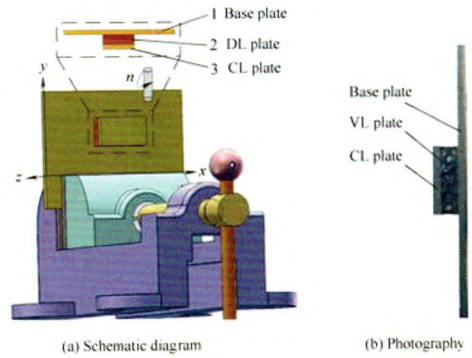
DOI 10.1007/s10033-017-0107-3

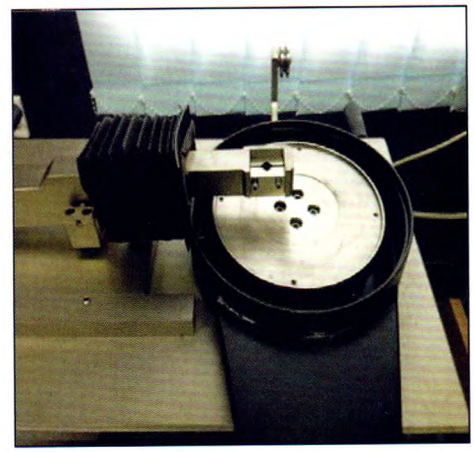
Abstract: The material removal rate and required workpiece surface quality of thin-walled structure milling are greatly limited due to its severe vibration, which is directly associated with the dynamic characteristics of the system. Therefore, the suppression of vibration is an unavoidable problem during milling. A novel partial surface damping method is proposed to modify the mode of the thin walled cantilever plate and to suppress vibration during milling. Based on classical plate theory, the design criterion is analyzed and configuration of the partial surface damper is introduced, in which viscoelastic plate and constraining plate are attached to the surface of the plate to increase the system's natural frequency and loss factor. In order to obtain the energy expression of the cutting system, the Ritz method is used to describe the unknown displacements. Then, with Lagrange's equation, the natural frequency and loss factor are calculated. In addition, the plate is divided into a finite number of square elements, and the regulation of treated position is studied based on theoretic and experimental analysis. The milling tests are conducted to verify its damping performance and the experimental results show that with treatment of partial surface damper, the deformation of the bare plate is reduced from 0.27 mm to 0.1 mm, while the vibration amplitude of the bare plate is reduced from 0.08 mm to 0.01 mm. The proposed research provides the instruction to design partial surface damper.



(a) Schematic diagram (b) Photography

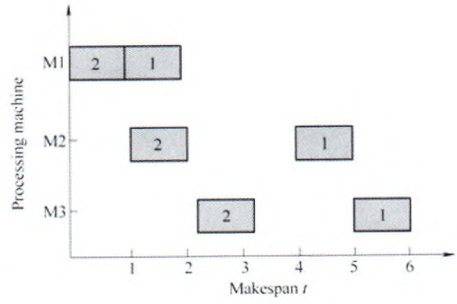
DOI 10.1007/s10033-017-0126-0

Abstract: In this study, the properties of hip implant material and lubricants were examined using a pin on disc apparatus, to compare the effect of metal-on-metal (MoM) contact with a bio-lubricant derived from palm oil. The behaviour of the lubricants was observed during the experiments, in which a hemispherical pin was loaded against a rotating disc with a groove. A titanium alloy was used to modify the hemispherical pin and disc. Before and after the experiments, the weight and surface roughness were analysed, to detect any degradation. The results were compared according to the different kinematic viscosities. The wear rates and level of friction with each lubricant were also examined. The lubricant with the highest viscosity had the lowest frictional value. Therefore, developing suitable lubricants has the potential to prolong the lifespan of prostheses or implants used in biomedical applications. The experiments collectively show that lubricants derived from palm oil could be used as efficient bio-lubricants in the future.



DOI 10.1007/s10033-017-0108-2

Abstract: Flow shop scheduling problem with time lags is a practical scheduling problem and attracts many studies. Permutation problem(PFSP with time lags) is concentrated but non-permutation problem(non-PFSP with time lags) seems to be neglected. With the aim to minimize the makespan and satisfy time lag constraints, efficient algorithms corresponding to PFSP and non-PFSP problems are proposed, which consist of iterated greedy algorithm for permutation(IGTLP) and iterated greedy algorithm for non-permutation (IGTLNP). The proposed algorithms are verified using well-known simple and complex instances of permutation and non-permutation problems with various time lag ranges. The permutation results indicate that the proposed IGTLP can reach near optimal solution within nearly 11% computational time of traditional GA approach. The non-permutation results indicate that the proposed IG can reach nearly same solution within less than 1% computational time compared with traditional GA approach. The proposed research combines PFSP and non-PFSP together with minimal and maximal time lag consideration, which provides an interesting viewpoint for industrial implementation.



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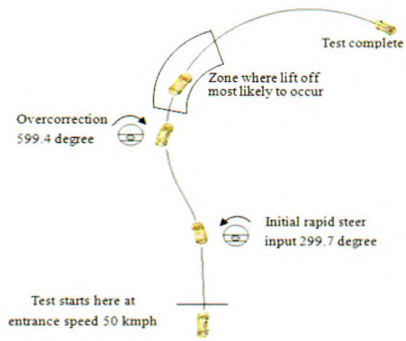
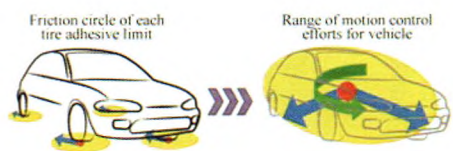
DOI 10.1007/s10033-017-0127-z

Abstract: Currently, many research from domestic and foreign on improving anti-rollover performance of vehicle mainly focus on the electronic control of auxiliary equipment, do not make full use of suspension layout to optimize anti-rollover performance of vehicle. This investigation into anti-rollover propensity improvement concentrates on the vehicle parameters greatly influencing on anti-rollover propensity of vehicle. A simulation based on fishhook procedure is used to perform design trials and evaluations aimed at ensuring an optimal balance between vehicle's design parameters and various engineering capacities, the anti-rollover propensity is optimized at the detailed design stage of a new SUV model. Firstly a four-DOF theoretical kinematic model is established, then a complete multi-body dynamics model built in ADAMS/car based on the whole vehicle parameters is correlated to the objective handing and stability test results of a mule car. Secondly, in fishhook test simulations, the Design of Experiments method is used to quantify the effect of the vehicle parameters on the anti-rollover performance. By means of the simulation, the roll center height of front suspension should be more than 30 mm, that of rear suspension less than 150 mm, and the HCG less than 620 mm for the SUV. The ratio of front to rear suspension roll stiffness should be ranged from 1.4 to 1.6 for the SUV. As a result, at the detailed design stage of product, the anti-rollover performance of vehicle can be improved by optimizing chassis and integrated vehicle parameters.



DOI 10.1007/s10033-017-0103-7

Abstract: The current research of the global chassis control problem for the full drive-by-wire vehicle focuses on the control allocation (CA) of the four-wheel-distributed traction/braking/steering systems. However, the path following performance and the handling stability of the vehicle can be enhanced a step further by automatically adjusting the vehicle speed to the optimal value. The optimal solution for the combined longitudinal and lateral motion control(MC) problem is given. First, a new variable step-size spatial transformation method is proposed and utilized in the prediction model to derive the dynamics of the vehicle with respect to the road, such that the tracking errors can be explicitly obtained over the prediction horizon at varying speeds. Second, a nonlinear model predictive control(NMPC) algorithm is introduced to handle the nonlinear coupling between any two directions of the vehicular planar motion and computes the sequence of the optimal motion states for following the desired path. Third, a hierarchical control structure is proposed to separate the motion controller into a NMPC based path planner and a terminal sliding mode control(TSMC) based path follower. As revealed through off-line simulations, the hierarchical methodology brings nearly 1700% improvement in computational efficiency without loss of control performance. Finally, the control algorithm is verified through a hardware in-the-loop simulation system. Double-lane-change(DLC) test results show that by using the optimal predictive controller, the root-mean-square(RMS) values of the lateral deviations and the orientation errors can be reduced by 41% and 30%, respectively, comparing to those by the optimal preview acceleration (OPA) driver model with the non-preview speed-tracking method. Additionally, the average vehicle speed is increased by 0.26 km/h with the peak sideslip angle suppressed to 1.9°. This research proposes a novel motion controller, which provides the full drive-by-wire vehicle with better lane-keeping and collision-avoidance capabilities during autonomous driving.



Reliability Engineering

DOI 10.1007/s10033-017-0095-3

Abstract: In this study, the relationship between the visual information gathered from the flame images and the excess air factor λ in coal burners is investigated. In conventional coal burners the excess air factor λ can be obtained using very expensive air measurement instruments. The proposed method to predict λ for a specific time in the coal burners consists of three distinct and consecutive stages; a) online flame images acquisition using a CCD camera, b) extraction meaningful information (flame intensity and brightness)from flame images, and c) learning these information (image features) with ANNs and estimate λ. Six different feature extraction methods have been used: CDF of Blue Channel, Co-Occurrence Matrix, L_∞-Frobenius Norms, Radiant Energy Signal (RES), PCA and Wavelet. When compared prediction results, it has seen that the use of co-occurrence matrix with ANNs has the best performance (RMSE=0.07) in terms of accuracy. The results show that the proposed predicting system using flame images can be preferred instead of using expensive devices to measure excess air factor in during combustion.

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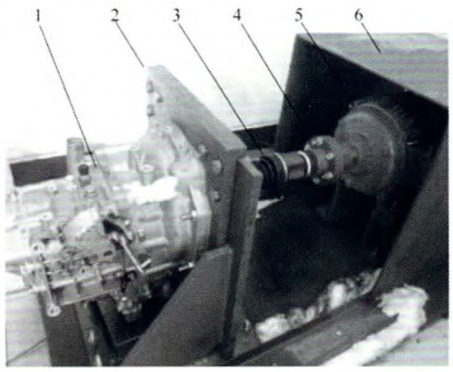

DOI 10.1007/s10033-017-0101-9

Abstract: In fault diagnosis of rotating machinery, Hilbert-Huang transform (HHT) is often used to extract the fault characteristic signal and analyze decomposition results in time-frequency domain. However, end effect occurs in HHT, which leads to a series of problems such as modal aliasing and false IMF(Intrinsic Mode Function). To counter such problems in HHT, a new method is put forward to process signal by combining the generalized regression neural network(GRNN) with the boundary local characteristic-scale continuation (BLCC). Firstly, the improved EMD(Empirical Mode Decomposition) method is used to inhibit the end effect problem that appeared in conventional EMD. Secondly, the generated IMF components are used in HHT. Simulation and measurement experiment for the cases of time domain, frequency domain and related parameters of Hilbert-Huang spectrum show that the method described here can restrain the end effect compared with the results obtained through mirror continuation, as the absolute percentage of the maximum mean of the beginning end point offset and the terminal point offset are reduced from 30.113% and 27.603% to 0.510% and 6.039% respectively, thus reducing the modal aliasing, and eliminating the false IMF components of HHT. The proposed method can effectively inhibit end effect, reduce modal aliasing and false IMF components, and show the real structure of signal components accurately.

DOI 10.1007/s10033-017-0098-0

Abstract: Aiming at the problem of low machining accuracy and uncontrollable thermal errors of NC machine tools, spindle thermal error measurement, modeling and compensation of a two turntable five-axis machine tool are researched. Measurement experiment of heat sources and thermal errors are carried out, and GRA(grey relational analysis) method is introduced into the selection of temperature variables used for thermal error modeling. In order to analyze the influence of different heat sources on spindle thermal errors, an ANN (artificial neural network) model is presented, and ABC(artificial bee colony) algorithm is introduced to train the link weights of ANN, a new ABC-NN(Artificial bee colony-based neural network) modeling method is proposed and used in the prediction of spindle thermal errors. In order to test the prediction performance of ABC-NN model, an experiment system is developed, the prediction results of LSR (least squares regression), ANN and ABC-NN are compared with the measurement results of spindle thermal errors. Experiment results show that the prediction accuracy of ABC-NN model is higher than LSR and ANN, and the residual error is smaller than 3μm, the new modeling method is feasible. The proposed research provides instruction to compensate thermal errors and improve machining accuracy of NC machine tools.

DOI 10.1007/s10033-017-0094-4

Abstract: The behavior of Taylor-Couette (TC) flow has been extensively studied. However, no suitable torque prediction models exist for high-capacity fluid machinery. The Eckhardt-Grossmann-Lohse(EGL) theory, derived based on the Navier–Stokes equations, is proposed to model torque behavior. This theory suggests that surfaces are the significant energy transfer interfaces between cylinders and annular flow. This study mainly focuses on the effects of surface texture on momentum transfer behavior through global torque measurement. First, a power-law torque behavior model is built to reveal the relationship between dimensionless torque and the Taylor number based on the EGL theory. Second, TC flow apparatus is designed and built based on the CNC machine tool to verify the torque behavior model. Third, four surface texture films are tested to check the effects of surface texture on momentum transfer. A stereo microscope and three-dimensional topography instrument are employed to analyze surface morphology. Global torque behavior is measured by rotating a multi component dynamometer, and the effects of surface texture on the annular flow behavior are observed via images obtained using a high-speed camera. Finally, torque behaviors under four different surface conditions are fitted and compared. The experimental results indicate that surface textures have a remarkable influence on torque behavior, and that the peak roughness of surface texture enhances the momentum transfer by strengthening the fluctuation in the TC flow.

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