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Quaternion-based Nonlinear Trajectory Tracking Control
of a Quadrotor Unmanned Aerial Vehicle.
ZHA Changliu, DING Xilun, YU Yushu, and WANG Xueqiang

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- 7 **Advances in Compact Manufacturing for Shape and Performance Controllability of Large-scale Components-A Review.** QIN Fangcheng, LI Yongtang, QI Huiping, and JU Li

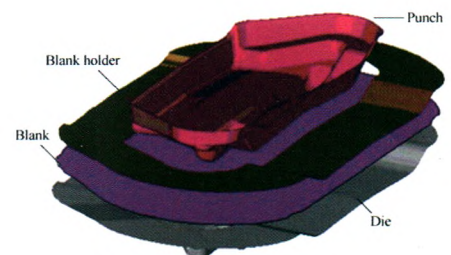
Abstract: Research on compact manufacturing technology for shape and performance controllability of metallic components can realize the simplification and high-reliability of manufacturing process on the premise of satisfying the requirement of macro/micro-structure. It is not only the key paths in improving performance, saving material and energy, and green manufacturing of components used in major equipments, but also the challenging subjects in frontiers of advanced plastic forming. To provide a novel horizon for the manufacturing in the critical components is significant. Focused on the high-performance large-scale components such as bearing rings, flanges, railway wheels, thick-walled pipes, etc, the conventional processes and their developing situations are summarized. The existing problems including multi-pass heating, wasting material and energy, high cost and high-emission are discussed, and the present study unable to meet the manufacturing in high-quality components is also pointed out. Thus, the new techniques related to casting-rolling compound precise forming of rings, compact manufacturing for duplex-metal composite rings, compact manufacturing for railway wheels, and casting-extruding continuous forming of thick-walled pipes are introduced in detail, respectively. The corresponding research contents, such as casting ring blank, hot ring rolling, near solid-state pressure forming, hot extruding, are elaborated. Some findings in through-thickness microstructure evolution and mechanical properties are also presented. The components produced by the new techniques are mainly characterized by fine and homogeneous grains. Moreover, the possible directions for further development of those techniques are suggested. Finally, the key scientific problems are first proposed. All of these results and conclusions have reference value and guiding significance for the integrated control of shape and performance in advanced compact manufacturing.



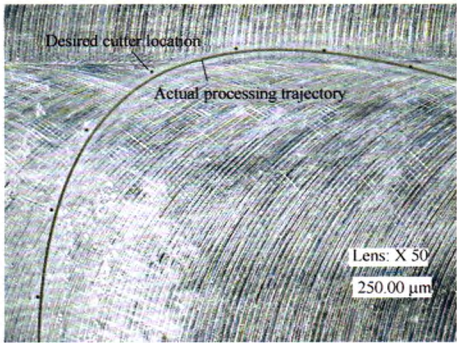
DOI: 10.3901/CJME.2016.1020.123

- 22 **Sheet Metal Forming Optimization by Using Surrogate Modeling Techniques.** WANG Hu, YE Fan, CHEN Lei, and LI Enying

Abstract: Surrogate assisted optimization has been widely applied in sheet metal forming design due to its efficiency. Therefore, to improve the efficiency of design and reduce the product development cycle, it is important for scholars and engineers to have some insight into the performance of each surrogate assisted optimization method and make them more flexible practically. For this purpose, the state-of-the-art surrogate assisted optimizations are investigated. Furthermore, in view of the bottleneck and development of the surrogate assisted optimization and sheet metal forming design, some important issues on the surrogate assisted optimization in support of the sheet metal forming design are analyzed and discussed, involving the description of the sheet metal forming design, off-line and online sampling strategies, space mapping algorithm, high dimensional problems, robust design, some challenges and potential feasible methods. Generally, this paper provides insightful observations into the performance and potential development of these methods in sheet metal forming design.

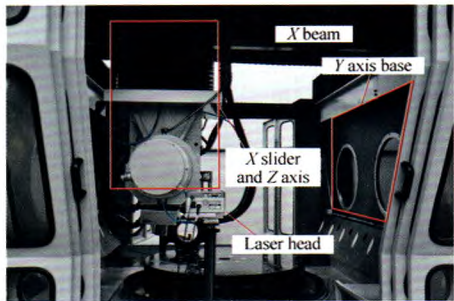


- 37
- DOI: 10.3901/CJME.2016.0127.015
- Pre-Compensation for Continuous-Path Running Trajectory Error in High-Speed Machining of Parts with Varied Curvature Features.** JIA Zhenyuan, SONG Dening, MA Jianwei, and GAO Yuanyuan



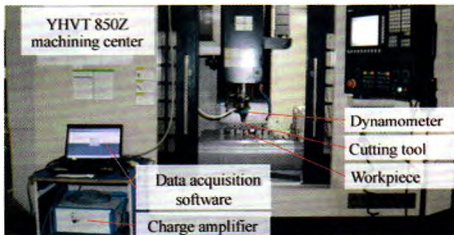
Abstract: Parts with varied curvature features play increasingly critical roles in engineering, and are often machined under high-speed continuous-path running mode to ensure the machining efficiency. However, the continuous-path running trajectory error is significant during high-feed-speed machining, which seriously restricts the machining precision for such parts with varied curvature features. In order to reduce the continuous-path running trajectory error without sacrificing the machining efficiency, a pre-compensation method for the trajectory error is proposed. Based on the formation mechanism of the continuous-path running trajectory error analyzed, this error is estimated in advance by approximating the desired toolpath with spline curves. Then, an iterative error pre-compensation method is presented. By machining with the regenerated toolpath after pre-compensation instead of the uncompensated toolpath, the continuous-path running trajectory error can be effectively decreased without the reduction of the feed speed. To demonstrate the feasibility of the proposed pre-compensation method, a heart curve toolpath that possesses varied curvature features is employed. Experimental results indicate that compared with the uncompensated processing trajectory, the maximum and average machining errors for the pre-compensated processing trajectory are reduced by 67.19% and 82.30%, respectively. An easy to implement solution for high efficiency and high precision machining of the parts with varied curvature features is provided.

- 46
- DOI: 10.3901/CJME.2016.0517.067
- Effect of Working Position on Vertical Motion Straightness of Open Hydrostatic Guideways in Grinding Machine.** ZHA Jun, WANG Zhiwei, XUE Fei, and CHEN Yaolong



Abstract: Hydrostatic guideways have various applications in precision machine tools due to their high motion accuracy. The analysis of motion straightness in hydrostatic guideways is generally ignoring the external load on the slider. A variation force also exists, caused by the different working positions, together with the dead load of the slider and that of other auxiliary devices. The effect of working position on vertical motion straightness is investigated based on the equivalent static model, considering the error averaging effort of pressured oil film in open hydrostatic guideways. Open hydrostatic guideways in LGF1000 are analyzed with this approach. The theoretical results show that the slider has maximum vertical motion straightness when the working position is closer the guiderail of Y axis. The vertical motion straightness reaches a minimum value as the working position is located at the center of the two guiderails on the Y axis. The difference between the maximum and minimum vertical motion straightness is 34.7%. The smaller vertical motion straightness is attributed to the smaller spacing of the two pads centers, along the Y direction. The experimental results show that the vertical motion straightness is $4.15\text{ }\mu\text{m}/1200\text{ mm}$, when the working position is located in the middle of the X beam, and $5.08\text{ }\mu\text{m}/1200\text{ mm}$, when the working position is approaching the Y guiderails, denoting an increase of 18.3%. The changing trends of the measured results validate the correctness of the theoretical model. The research work can be used to reveal the variation law of accuracy of the open hydrostatic guideways, under different working positions, to predict the machining precision, and provides the basis for an error compensation strategy for gantry type grinding machines.

- 53
- DOI: 10.3901/CJME.2015.0405.045
- Effects of Cutting Parameters on Tool Insert Wear in End Milling of Titanium Alloy Ti6Al4V.** LUO Ming, WANG Jing, WU Baohai, and ZHANG Dinghua

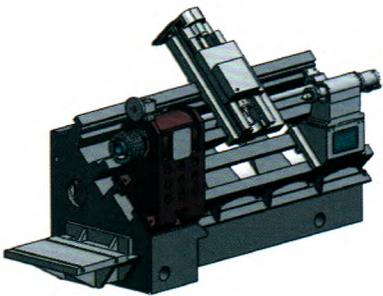


Abstract: Titanium alloy is a kind of typical hard-to-cut material due to its low thermal conductivity and high strength at elevated temperatures, this contributes to the fast tool wear in the milling of titanium alloys. The influence of cutting conditions on tool wear has been focused on the turning process, and their influence on tool wear in milling process as well as the influence of tool wear on cutting force coefficients has not been investigated comprehensively. To fully understand the tool wear behavior in milling process with inserts, the influence of cutting parameters on tool wear in the milling of titanium alloys Ti6Al4V by using indexable cutters is investigated. The tool wear rate and trends under different feed per tooth, cutting speed, axial depth of cut and radial depth of cut are analyzed. The results show that the feed rate per tooth and the radial depth of cut have a large influence on tool wear in milling Ti6Al4V with coated insert. To reduce tool wear, cutting parameters for coated inserts under experimental cutting conditions are set as: feed rate per tooth less than 0.07 mm , radial depth of cut less than 1.0 mm , and cutting speed sets between 60 and 150 m/min . Investigation on the relationship between tool wear and cutting force coefficients shows that tangential edge constant increases with tool wear and cutter edge chipping can lead to a great variety of tangential cutting force coefficient. The proposed research provides the basic data for evaluating the machinability of milling Ti6Al4V alloy with coated inserts, and the recommend cutting parameters can be immediately applied in practical production.

DOI: 10.3901/CJME.2016.0113.007

- 60 **Applying CBR to Machine Tool Product Configuration Design Oriented to Customer Requirements.** WANG Pengjia, GONG Yadong, XIE Hualong, LIU Yongxian, and NEE Andrew Yehching

Abstract: Product customization is a trend in the current market-oriented manufacturing environment. However, deduction from customer requirements to design results and evaluation of design alternatives are still heavily reliant on the designer's experience and knowledge. To solve the problem of fuzziness and uncertainty of customer requirements in product configuration, an analysis method based on the grey rough model is presented. The customer requirements can be converted into technical characteristics effectively. In addition, an optimization decision model for product planning is established to help the enterprises select the key technical characteristics under the constraints of cost and time to serve the customer to maximal satisfaction. A new case retrieval approach that combines the self-organizing map and fuzzy similarity priority ratio method is proposed in case-based design. The self-organizing map can reduce the retrieval range and increase the retrieval efficiency, and the fuzzy similarity priority ratio method can evaluate the similarity of cases comprehensively. To ensure that the final case has the best overall performance, an evaluation method of similar cases based on grey correlation analysis is proposed to evaluate similar cases to select the most suitable case. Furthermore, a computer-aided system is developed using MATLAB GUI to assist the product configuration design. The actual example and result on an ETC series machine tool product show that the proposed method is effective, rapid and accurate in the process of product configuration. The proposed methodology provides a detailed instruction for the product configuration design oriented to customer requirements.

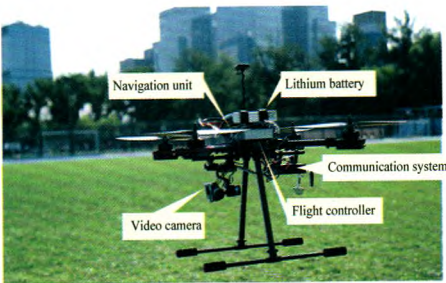


Transport Engineering

DOI: 10.3901/CJME.2016.1026.127

- 77 **Quaternion-based Nonlinear Trajectory Tracking Control of a Quadrotor Unmanned Aerial Vehicle.** ZHA Changliu, DING Xilun, YU Yushu, and WANG Xueqiang

Abstract: At present, most controllers of quadrotor unmanned aerial vehicles(UAVs) use Euler angles to express attitude. These controllers suffer a singularity problem when the pitch angle is near 90°, which limits the maneuverability of the UAV. To overcome this problem, based on the quaternion attitude representation, a 6 degree of freedom(DOF) nonlinear controller of a quadrotor UAV is designed using the trajectory linearization control(TLC) method. The overall controller contains a position sub-controller and an attitude sub-controller. The two controllers regulate the translational and rotational motion of the UAV, respectively. The controller is improved by using the commanded value instead of the nominal value as the input of the inner control loop. The performance of controller is tested by simulation before and after the improvement, the results show that the improved controller is better. The proposed controller is also tested via numerical simulation and real flights and is compared with the traditional controller based on Euler angles. The test results confirm the feasibility and the robustness of the proposed nonlinear controller. The proposed controller can successfully solve the singularity problem that usually occurs in the current attitude control of UAV and it is easy to be realized.

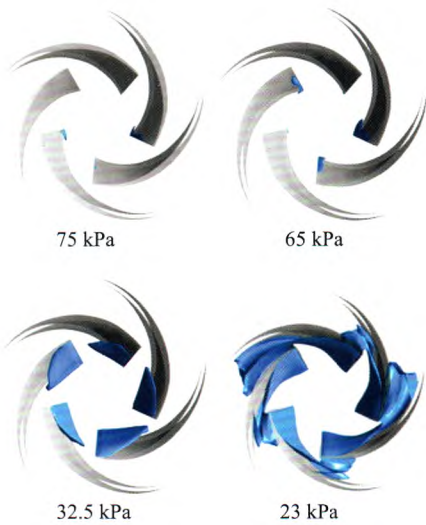


DOI: 10.3901/CJME.2016.1018.121

- 93 **Investigation into the Vibration of Metro Bogies Induced by Rail Corrugation.** LING Liang, LI Wei, FOO Elbert, WU Lei, WEN Zefeng, and JIN Xuesong

Abstract: The current research of rail corrugation mainly focuses on the mechanisms of its formation and development. Compared with the root causes and development mechanisms, the wheel-rail impacts, the fatigue failure of vehicle-track parts, and the loss of ride comfort due to rail corrugation should also be taken into account. However, the influences of rail corrugation on vehicle and track vibration, and failure of vehicle and track structural parts are barely discussed in the literature. This paper presents an experimental and numerical investigation of the structural vibration of metro bogies caused by rail corrugation. Extensive experiments are conducted to investigate the effects of short-pitch rail corrugation on the vibration accelerations of metro bogies. A dynamic model of a metro vehicle coupled with a concrete track is established to study the influence of rail corrugation on the structural vibration of metro bogies. The field test results indicate that the short-pitch rail corrugation generates strong vibrations on the axle-boxes and the bogie frames, therefore, accelerates the fatigue failure of the bogie components. The numerical results show that short-pitch rail corrugation may largely reduce the fatigue life of the coil spring, and improving the damping value of the primary vertical dampers is likely to reduce the strong vibration induced by short-pitch rail corrugation. This research systematically studies the effect of rail corrugation on the vibration of metro bogies and proposes some remedies for mitigating strong vibrations of metro bogies and reducing the incidence of failure in primary coil springs, which would be helpful in developing new metro bogies and track maintenance procedures.

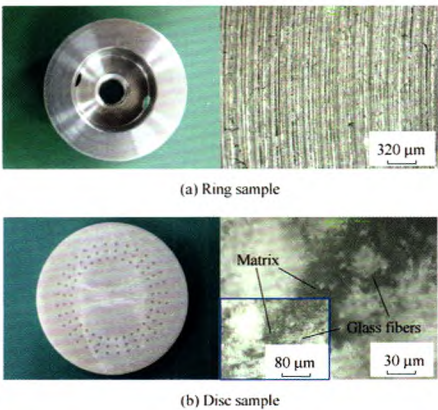




DOI: 10.3901/CJME.2016.1024.125

103 **Cavitation Optimization for a Centrifugal Pump Impeller by Using Orthogonal Design of Experiment.** PEI Ji, YIN Tingyun, YUAN Shouqi, WANG Wenjie, and WANG Jiabin

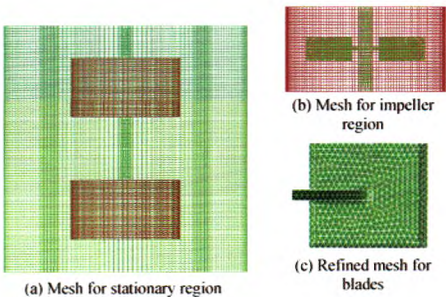
Abstract: Cavitation is one of the most important performance of centrifugal pumps. However, the current optimization works of centrifugal pump are mostly focusing on hydraulic efficiency only, which may result in poor cavitation performance. Therefore, it is necessary to find an appropriate solution to improve cavitation performance with acceptable efficiency. In this paper, to improve the cavitation performance of a centrifugal pump with a vaned diffuser, the influence of impeller geometric parameters on the cavitation of the pump is investigated using the orthogonal design of experiment (DOE) based on computational fluid dynamics. The impeller inlet diameter D_1 , inlet incidence angle $\Delta\beta$, and blade wrap angle φ are selected as the main impeller geometric parameters and the orthogonal experiment of $L_9(3^3)$ is performed. Three-dimensional steady simulations for cavitation are conducted by using constant gas mass fraction model with second-order upwind, and the predicated cavitation performance is validated by laboratory experiment. The optimization results are obtained by the range analysis method to improve cavitation performance without obvious decreasing the efficiency of the centrifugal pump. The internal flow of the pump is analyzed in order to identify the flow behavior that can affect cavitation performance. The results show that D_1 has the greatest influence on the pump cavitation and the final optimized impeller provides better flow distribution at blade leading edge. The final optimized impeller accomplishes better cavitation and hydraulic performance and the NPSHR decreases by 0.63m compared with the original one. The presented work supplies a feasible route in engineering practice to optimize a centrifugal pump impeller for better cavitation performance.



DOI: 10.3901/CJME.2016.0620.075

110 **Experimental Study on Influence of Dimples on Lubrication Performance of Glass Fiber-epoxy Resin Composite under Natural Seawater Lubrication.** WU Shaofeng, GAO Dianrong, LIANG Yingna, and CHEN Bo

Abstract: Bionic non-smooth surface is widely applied in metal and ceramics materials. In order to introduce this technology to high pressure seawater pump, the influence of bionic non-smooth surface on the engineering plastics used in pump should be investigated. The comparative tests are carried out with a ring-on-disc configuration under 800, 1000, 1200 and 1400 r/min in order to research the influence of the bionic non-smooth surface on glass fiber-epoxy resin composite(GF/EPR) under natural seawater lubrication. The disc surfaces are textured with five kinds of pits, which are semi-spherical, conical, cone-cylinder combined, cylindrical pits and through holes, respectively. A smooth surface is tested as reference. The results show that the lubrication performance of dimpled GF/EPR sample is much better than that of the smooth sample under all rotational speeds. The semi-spherical pits surface has more obvious friction reduction than the others, which shows that the least reduction is approximately 43.29% of smooth surface under 1200 r/min. However, the wear level is only marginally influenced by dimples. The surface morphology investigations disclose severe modifications caused by abrasive wear primarily. The results are helpful to vary friction properties of GF/EPR by non-smooth surface, or provide references to the design of non-smooth surfaces under certain condition.



DOI: 10.3901/CJME.2016.1107.129

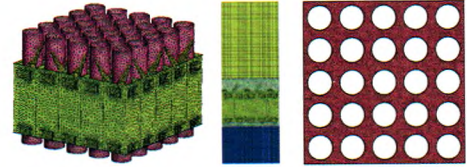
118 **CFD Simulation of Local and Global Mixing Time in an Agitated Tank.** LI Liangchao and XU Bin

Abstract: The Issue of mixing efficiency in agitated tanks has drawn serious concern in many industrial processes. The turbulence model is very critical to predicting mixing process in agitated tanks. On the basis of computational fluid dynamics(CFD) software package Fluent 6.2, the mixing characteristics in a tank agitated by dual six-blade-Rushton-turbines(6-DT) are predicted using the detached eddy simulation(DES) method. A sliding mesh(SM) approach is adopted to solve the rotation of the impeller. The simulated flow patterns and liquid velocities in the agitated tank are verified by experimental data in the literature. The simulation results indicate that the DES method can obtain more flow details than Reynolds-averaged Navier-Stokes(RANS) model. Local and global mixing time in the agitated tank is predicted by solving a tracer concentration scalar transport equation. The simulated results show that feeding points have great influence on mixing process and mixing time. Mixing efficiency is the highest for the feeding point at location of midway of the two impellers. Two methods are used to determine global mixing time and get close result. Dimensionless global mixing time remains unchanged with increasing of impeller speed. Parallel, merging and diverging flow pattern form in the agitated tank, respectively, by changing the impeller spacing and clearance of lower impeller from the bottom of the tank. The global mixing time is the shortest for the merging flow, followed by diverging flow, and the longest for parallel flow. The research presents helpful references for design, optimization and scale-up of agitated tanks with multi-impeller.

DOI: 10.3901/CJME.2016.0621.076

- 127 **Heat Transfer Enhancement with Mixing Vane Spacers Using the Field Synergy Principle.** YANG Lixin, ZHOU Mengjun, and TIAN Zihao

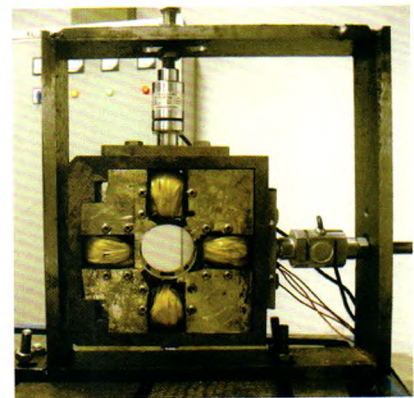
Abstract: The single-phase heat transfer characteristics in a PWR fuel assembly are important. Many investigations attempt to obtain the heat transfer characteristics by studying the flow features in a 5×5 rod bundle with a spacer grid. The field synergy principle is used to discuss the mechanism of heat transfer enhancement using mixing vanes according to computational fluid dynamics results, including a spacer grid without mixing vanes, one with a split mixing vane, and one with a separate mixing vane. The results show that the field synergy principle is feasible to explain the mechanism of heat transfer enhancement in a fuel assembly. The enhancement in subchannels is more effective than on the rod's surface. If the pressure loss is ignored, the performance of the split mixing vane is superior to the separate mixing vane based on the enhanced heat transfer. Increasing the blending angle of the split mixing vane improves heat transfer enhancement, the maximum of which is 7.1%. Increasing the blending angle of the separate mixing vane did not significantly enhance heat transfer in the rod bundle, and even prevented heat transfer at a blending angle of 50° . This finding testifies to the feasibility of predicting heat transfer in a rod bundle with a spacer grid by field synergy, and upon comparison with analyzed flow features only, the field synergy method may provide more accurate guidance for optimizing the use of mixing vanes.



DOI: 10.3901/CJME.2016.0129.017

- 135 **Non-Contact Electromagnetic Exciter Design with Linear Control Method.** WANG Lin, XIONG Xianzhi, and XU Hua

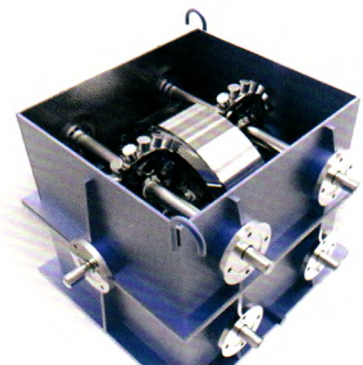
Abstract: A non-contact type force actuator is necessary for studying the dynamic performance of a high-speed spindle system owing to its high-speed operating conditions. A non-contact electromagnetic exciter is designed for identifying the dynamic coefficients of journal bearings in high-speed grinding spindles. A linear force control method is developed based on PID controller. The influence of amplitude and frequency of current, misalignment and rotational speed on magnetic field and excitation force is investigated based on two-dimensional finite element analysis. The electromagnetic excitation force is measured with the auxiliary coils and calibrated by load cells. The design is validated by the experimental results. Theoretical and experimental investigations show that the proposed design can accurately generate linear excitation force with sufficiently large amplitude and higher signal to noise ratio. Moreover, the fluctuations in force amplitude are reduced to a greater extent with the designed linear control method even when the air gap changes due to the rotor vibration at high-speed conditions. Besides, it is possible to apply various types of excitations: constant, synchronous, and non-synchronous excitation forces based on the proposed linear control method. This exciter can be used as linear-force exciting and controlling system for dynamic performance study of different high-speed rotor-bearing systems.



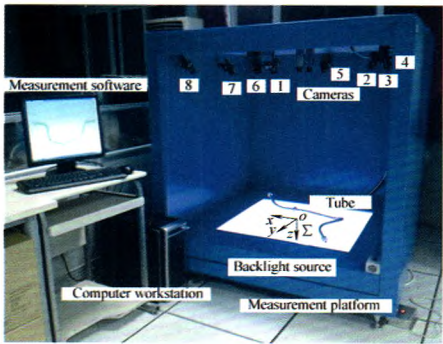
DOI: 10.3901/CJME.2016.1025.126

- 144 **Optimal Design for an End Face Engagement Worm Gear with Multiple Worm-wheel Meshing.** DENG Xingqiao, ZHU Weibing, CHEN Yonghong, CHEN Shouan, and WANG Jing

Abstract: To solve the problem for lacking a special mechanical transmission that could provide multiple outputs with high transmission efficiency and good lubrication in the modern industrial, a novel worm gear, named end face engagement worm gear, with multiple worm-wheel meshing is proposed for the first time. The essential parameters for the worm gear are optimized to enhance lubrication and meshing properties. Moreover, analysis of variance (ANOVA) is applied to determine the optimum levels and to determine the influence of parameters. The ANOVA results show that the novel end face engagement worm gear with multiple worm wheels provides high lubrication (the lubrication angle is more than 89°) and meshing performance (the induce normal curvature is less than 0.0002 mm^{-1}). The interaction between center distance and roller slant distance most strongly influences the lubrication angle (contributed 51.6%), followed by the parameters of center distance (contributed 25.0%), roller slant distance (contributed 16.4%), tooth angle of gear, gear ratio, and roller radius. In addition, roller radius most strongly influences the induced normal curvature (contributed 39.4%), followed by roller slant distance (contributed 15.2%), tooth angle of the gear (contributed 9.0%), center distance, and gear ratio. The proposed worm gear helps to enrich the no-backlash high precision worm drive and the optimal design method can provide a useful reference on performance improvement of other worm gear.



Reliability Engineering

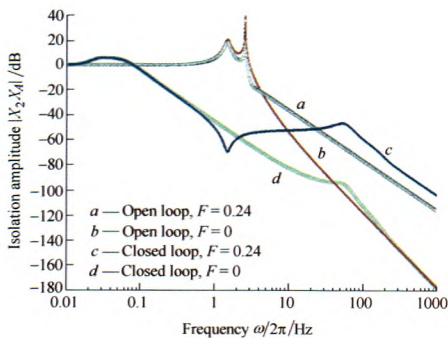


152 DOI: 10.3901/CJME.2016.0516.066
Accurate Measurement Method for Tube's Endpoints Based on Machine Vision. LIU Shaoli, JIN Peng, LIU Jianhua, WANG Xiao, and SUN Peng

Abstract: Tubes are used widely in aerospace vehicles, and their accurate assembly can directly affect the assembling reliability and the quality of products. It is important to measure the processed tube's endpoints and then fix any geometric errors correspondingly. However, the traditional tube inspection method is time-consuming and complex operations. Therefore, a new measurement method for a tube's endpoints based on machine vision is proposed. First, reflected light on tube's surface can be removed by using photometric linearization. Then, based on the optimization model for the tube's endpoint measurements and the principle of stereo matching, the global coordinates and the relative distance of the tube's endpoint are obtained. To confirm the feasibility, 11 tubes are processed to remove the reflected light and then the endpoint's positions of tubes are measured. The experiment results show that the measurement repeatability accuracy is 0.167 mm, and the absolute accuracy is 0.328 mm. The measurement takes less than 1 min. The proposed method based on machine vision can measure the tube's endpoints without any surface treatment or any tools and can realize on line measurement.

164 DOI: 10.3901/CJME.2016.0428.062
Active Low-frequency Vertical Vibration Isolation System for Precision Measurements. WU Kang, LI Gang, HU Hua, and WANG Lijun

Abstract: Low-frequency vertical vibration isolation systems play important roles in precision measurements to reduce seismic and environmental vibration noise. Several types of active vibration isolation systems have been developed. However, few researches focus on how to optimize the test mass install position in order to improve the vibration transmissibility. An active low-frequency vertical vibration isolation system based on an earlier instrument, the Super Spring, is designed and implemented. The system, which is simple and compact, consists of two stages: a parallelogram-shaped linkage to ensure vertical motion, and a simple spring-mass system. The theoretical analysis of the vibration isolation system is presented, including terms erroneously ignored before. By carefully choosing the mechanical parameters according to the above analysis and using feedback control, the resonance frequency of the system is reduced from 2.3 to 0.03 Hz, a reduction by a factor of more than 75. The vibration isolation system is installed as an inertial reference in an absolute gravimeter, where it improved the scatter of the absolute gravity values by a factor of 5. The experimental results verifies the improved performance of the isolation system, making it particularly suitable for precision experiments. The improved vertical vibration isolation system can be used as a prototype for designing high-performance active vertical isolation systems. An improved theoretical model of this active vibration isolation system with beam-pivot configuration is proposed, providing fundamental guidelines for vibration isolator design and assembling.



170 DOI: 10.3901/CJME.2016.1019.122
High Precision Ultrasonic Guided Wave Technique for Inspection of Power Transmission Line. CHENG Jun, QIU Jinhao, JI Hongli, WANG Enrong, TAKAGI Toshiyuki, and UCHIMOTO Tetsuya

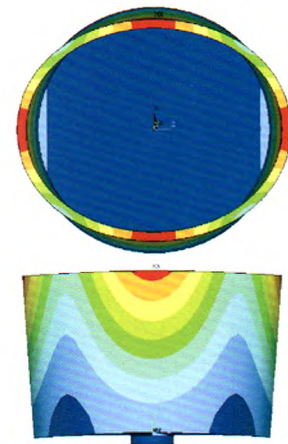
Abstract: Due to the merits of high inspection speed and long detecting distance, Ultrasonic Guided Wave(UGW) method has been commonly applied to the on-line maintenance of power transmission line. However, the guided wave propagation in this structure is very complicated, leading to the unfavorable defect localization accuracy. Aiming at this situation, a high precision UGW technique for inspection of local surface defect in power transmission line is proposed. The technique is realized by adopting a novel segmental piezoelectric ring transducer and transducer mounting scheme, combining with the comprehensive characterization of wave propagation and circumferential defect positioning with multiple piezoelectric elements. Firstly, the propagation path of guided waves in the multi-wires of transmission line under the proposed technique condition is investigated experimentally. Next, the wave velocities are calculated by dispersion curves and experiment test respectively, and from comparing of the two results, the guided wave mode propagated in transmission line is confirmed to be F(1,1) mode. Finally, the axial and circumferential positioning of local defective wires in transmission line are both achieved, by using multiple piezoelectric elements to surround the stands and send elastic waves into every single wire. The proposed research can play a role of guiding the development of highly effective UGW method and detecting system for multi-wire transmission line.



DOI: 10.3901/CJME.2016.0520.070

180 **Modeling and Analysis of Mechanical Quality Factor of the Resonator for Cylinder Vibratory Gyroscope.** XI Xiang, WU Xuezhong, WU Yulie, and ZHANG Yongmeng

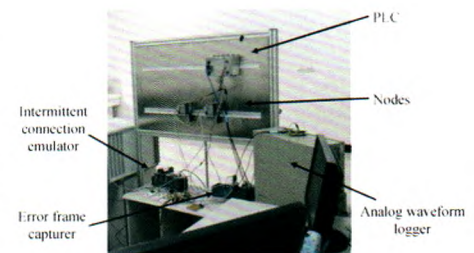
Abstract: Mechanical Quality factor(Q factor) of the resonator is an important parameter for the cylinder vibratory gyroscope(CVG). Traditional analytical methods mainly focus on a partial energy loss during the vibration process of the CVG resonator, thus are not accurate for the mechanical Q factor prediction. Therefore an integrated model including air damping loss, surface defect loss, support loss, thermoelastic damping loss and internal friction loss is proposed to obtain the mechanical Q factor of the CVG resonator. Based on structural dynamics and energy dissipation analysis, the contribution of each energy loss to the total mechanical Q factor is quantificationally analyzed. For the resonator with radius ranging from 10 mm to 20 mm, its mechanical Q factor is mainly related to the support loss, thermoelastic damping loss and internal friction loss, which are fundamentally determined by the geometric sizes and material properties of the resonator. In addition, resonators made of alloy 3J53 (Ni42CrTiAl), with different sizes, were experimentally fabricated to test the mechanical Q factor. The theoretical model is well verified by the experimental data, thus provides an effective theoretical method to design and predict the mechanical Q factor of the CVG resonator.



DOI: 10.3901/CJME.2016.1021.124

190 **Data Driven CAN Node Reliability Assessment for Manufacturing System.** ZHANG Leiming, YUAN Yong, and LEI Yong

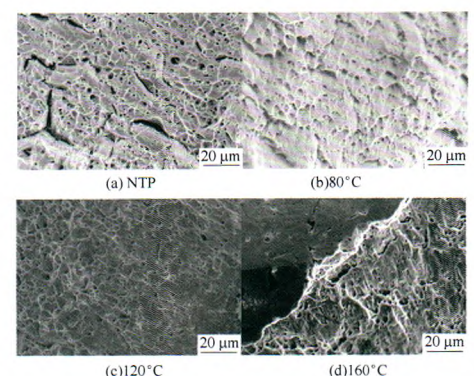
Abstract: The reliability of the Controller Area Network(CAN) is critical to the performance and safety of the system. However, direct bus-off time assessment tools are lacking in practice due to inaccessibility of the node information and the complexity of the node interactions upon errors. In order to measure the mean time to bus-off(MTTB) of all the nodes, a novel data driven node bus-off time assessment method for CAN network is proposed by directly using network error information. First, the corresponding network error event sequence for each node is constructed using multiple-layer network error information. Then, the generalized zero inflated Poisson process(GZIP) model is established for each node based on the error event sequence. Finally, the stochastic model is constructed to predict the MTTB of the node. The accelerated case studies with different error injection rates are conducted on a laboratory network to demonstrate the proposed method, where the network errors are generated by a computer controlled error injection system. Experiment results show that the MTTB of nodes predicted by the proposed method agree well with observations in the case studies. The proposed data driven node time to bus-off assessment method for CAN networks can successfully predict the MTTB of nodes by directly using network error event data.

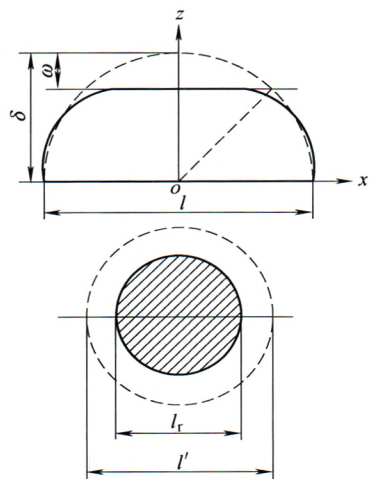


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200 **Effects of Temperature and Pressure on Stress Corrosion Cracking Behavior of 310S Stainless Steel in Chloride Solution.** ZHONG Yunpan, ZHOU Cheng, CHEN Songying, and WANG Ruiyan

Abstract: 310S is an austenitic stainless steel for high temperature applications, having strong resistance of oxidation, hydrogen embrittlement and corrosion. Stress corrosion cracking(SCC) is the main corrosion failure mode for 310S stainless steel. Past researched about SCC of 310S primarily focus on the corrosion mechanism and influence of temperature and corrosive media, but few studies concern the combined influence of temperature, pressure and chloride. For a better understanding of temperature and pressure's effects on SCC of 310S stainless steel, prepared samples are investigated via slow strain rate tensile test(SSRT) in different temperature and pressure in NACE A solution. The result shows that the SCC sensibility indexes of 310S stainless steel increase with the rise of temperature and reach maximum at 10MPa and 160°C, increasing by 22.3% compared with that at 10 MPa and 80 °C. Instead, the sensibility decreases with the pressure up. Besides, the fractures begin to transform from the ductile fracture to the brittle fracture with the increase of temperature. 310S stainless steel has an obvious tendency of stress corrosion at 10MPa and 160°C and the fracture surface exists cleavage steps, river patterns and some local secondary cracks, having obvious brittle fracture characteristics. The SCC cracks initiate from inclusions and tiny pits in the matrix and propagate into the matrix along the cross section gradually until rupture. In particular, the oxygen and chloride play an important role on the SCC of 310S stainless steel in NACE A solution. The chloride damages passivating film, causing pitting corrosion, concentrating in the cracks and accelerated SSC ultimately. The research reveals the combined influence of temperature, pressure and chloride on the SCC of 310S, which can be a guide to the application of 310S stainless steel in super-heater tube.





207 [DOI: 10.3901/CJME.2016.0624.079](https://doi.org/10.3901/CJME.2016.0624.079)
Elastoplastic Contact Mechanics Model of Rough Surface Based on Fractal Theory. YUAN Yuan, GAN Li, LIU Kai, and YANG Xiaohui

Abstract: Because the result of the MB fractal model contradicts with the classical contact mechanics, a revised elastoplastic contact model of a single asperity is developed based on fractal theory. The critical areas of a single asperity are scale dependent, with an increase in the contact load and contact area, a transition from elastic, elastoplastic to full plastic deformation takes place in this order. In considering the size distribution function, analytic expression between the total contact load and the real contact area on the contact surface is obtained. The elastic, elastoplastic and full plastic contact load are obtained by the critical elastic contact area of the biggest asperity and maximum contact area of a single asperity. The results show that a rough surface is firstly in elastic deformation. As the load increases, elastoplastic or full plastic deformation takes place. For constant characteristic length scale G , the slope of load-area relation is proportional to fractal dimension D . For constant fractal dimension D , the slope of load-area relation is inversely proportional to G . For constant D and G , the slope of load-area relation is inversely proportional to property of the material ϕ , namely with the same load, the material of rough surface is softer, and the total contact area is larger. The contact mechanics model provides a foundation for study of the friction, wear and seal performance of rough surfaces.

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