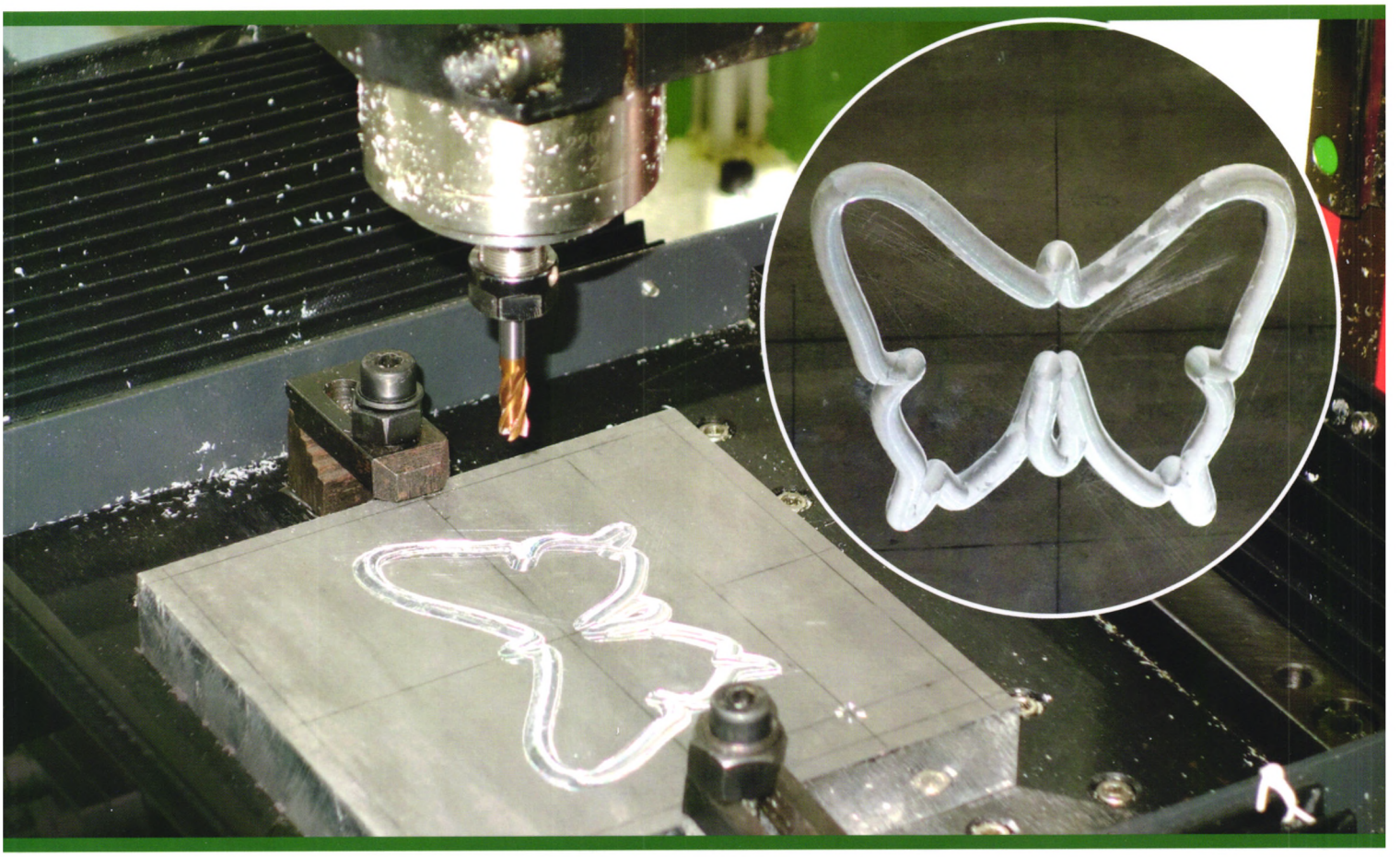
ISSN 1000-9345 • e-ISSN 2192-8258
CN 11-2737/TH • CODEN CJMEER

CHINESE JOURNAL OF MECHANICAL ENGINEERING®

中国机械工程学报



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September 2016

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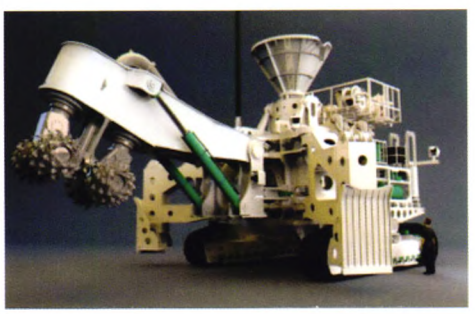
CHINESE JOURNAL OF MECHANICAL ENGINEERING

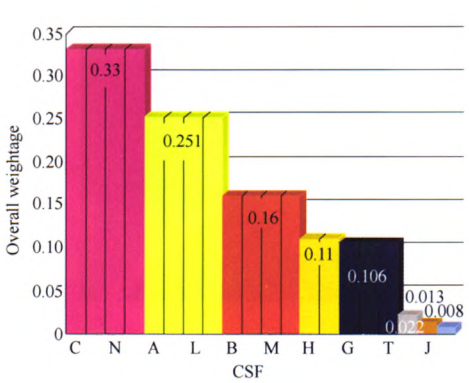
Review



Abstract: seafloor massive sulfide(SMS) deposits which consist of Au, Ag, Cu, and other metal elements, have been a target of commercial mining in recent decades. The demand for established and reliable commercial mining tools for SMS deposits is increasing within the marine mining industry. The current status and progress of mining technology and equipment for SMS deposits are introduced. First, the mining technology and other recent developments of SMS deposits are comprehensively explained and analyzed. The seafloor production tools manufactured by Nautilus Minerals and similar mining tools from Japan for SMS deposits are compared and discussed in turn. Second, SMS deposit mining technology research being conducted in China is described, and a new SMS deposits mining tool is designed according to the environmental requirement. Final, some new trends of mining technology of SMS deposits are summarized and analyzed. All of these conclusions and results have reference value and guiding significance for the research of SMS deposit mining in China.

Abstract: Mechanical transmissions are applied widely in various electrical and mechanical products, but some qualities of some high-end products can't meet people's demand, and need to be improved with some new methods or theories. The fractal theory is a new mathematic tool, which provides a new approach for the further study in the area of the mechanical transmission, and helps to solve some problems. The basic contents of the fractal theory are introduced firstly, especially the two important concepts, the self-similar fractal and the fractal dimension. Then, the deferent application of the fractal theory in this area are given to display how to further the study and improve some important characteristics of the mechanical transmission, such as contact surfaces, manufacturing precise, friction and wear, stiffness, strength, dynamics, fault diagnosis, etc. Finally, the problems of the fractal theory and its application are discussed, and some weaknesses, such as the calculation capacity of the fractal theory is not strong, are pointed out. Some new solutions are suggested, such as combining the fractal theory with the fuzzy theory, the chaos theory and so on. The new application fields of the fractal theory in the area of the mechanical transmission are proposed.

Advanced Manufacturing and Machining Technology



Abstract: Manufacturing industries are facing challenges in the implementation of agile manufacturing in their products and processes. Agility is widely accepted as a new competitive concept in the manufacturing sector in fulfilling varying customer demand. Thus, evaluation of agile manufacturing in industries has become a necessity. The success of an organisation depends on its ability to manage finding the critical success factors and give them special and continued attention in order to bring about high performance. This paper proposes a set of critical success factors (CSFs) for evaluating agile manufacturing considered appropriate for the manufacturing sector. The analytical hierarchy process (AHP) method is applied for prioritizing the success factors, by summarizing the opinions of experts. It is believed that the proposed CSFs enable and assist manufacturing industries to achieve a higher performance in agile manufacturing so as to increase competitiveness.

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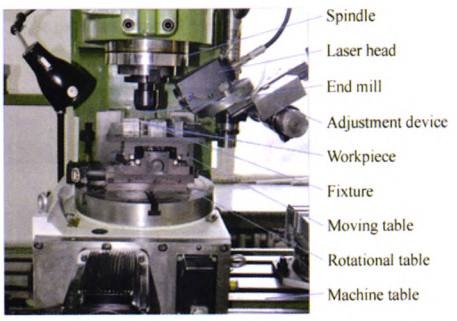
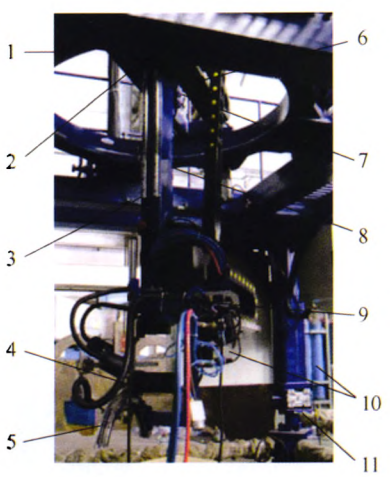
DOI: 10.3901/CJME.2016.0303.024

Abstract: Laser assisted machining is an effective method to machine advanced materials with the added benefits of longer tool life and increased material removal rates. While extensive studies have investigated the machining properties for laser assisted milling(LAML), few attempts have been made to extend LAML to machining parts with complex geometric features. A methodology for continuous path machining for LAML is developed by integration of a rotary and movable table into an ordinary milling machine with a laser beam system. The machining strategy and processing path are investigated to determine alignment of the machining path with the laser spot. In order to keep the material removal temperatures above the softening temperature of silicon nitride, the transformation is coordinated and the temperature interpolated, establishing a transient thermal model. The temperatures of the laser center and cutting zone are also carefully controlled to achieve optimal machining results and avoid thermal damage. These experiments indicate that the system results in no surface damage as well as good surface roughness, validating the application of this machining strategy and thermal model in the development of a new LAML system for continuous path processing of silicon nitride. The proposed approach can be easily applied in LAML system to achieve continuous processing and improve efficiency in laser assisted machining.



DOI: 10.3901/CJME.2016.0425.059

Abstract: The current research of processing large size fabrication holes on complex spatial curved surface mainly focuses on the CNC flame cutting machines design for ship hull of ship manufacturing. However, the existing machines cannot meet the continuous cutting requirements with variable pass conditions through their fixed configuration, and cannot realize high-precision processing as the accuracy theory is not studied adequately. This paper deals with structure design and accuracy prediction technology of novel machine tools for solving the problem of continuous and high-precision cutting. The needed variable trajectory and variable pose kinematic characteristics of non-contact cutting tool are figured out and a metamorphic CNC flame cutting machine designed through metamorphic principle is presented. To analyze kinematic accuracy of the machine, models of joint clearances, manufacturing tolerances and errors in the input variables and error models considering the combined effects are derived based on screw theory after establishing ideal kinematic models. Numerical simulations, processing experiment and trajectory tracking experiment are conducted relative to an eccentric hole with bevels on cylindrical surface respectively. The results of cutting pass contour and kinematic error interval which the position error is from –0.975 mm to +0.628 mm and orientation error is from –0.01 rad to +0.01 rad indicate that the developed machine can complete cutting process continuously and effectively, and the established kinematic error models are effective although the interval is within a 'large' range. It also shows the matching property between metamorphic principle and variable working tasks, and the mapping correlation between original designing parameters and kinematic errors of machines. This research develops a metamorphic CNC flame cutting machine and establishes kinematic error models for accuracy analysis of machine tools.



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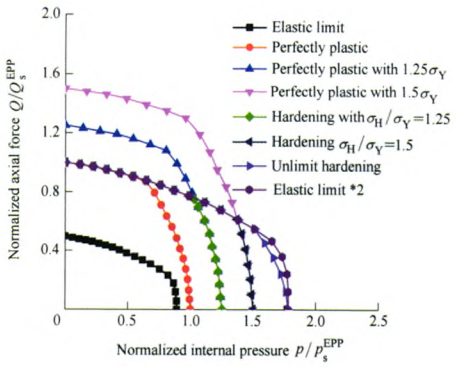
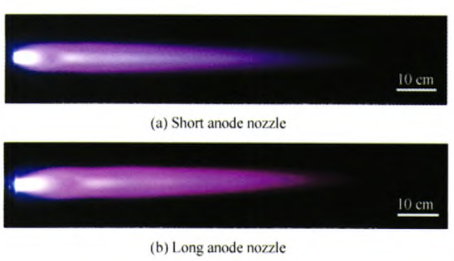


DOI: 10.3901/CJME.2016.0304.025

General Analytical Shakedown Solution for Structures with Kinematic Hardening Materials. GUO Baofeng, ZOU Zongyuan, and JIN Miao

Abstract: The effect of kinematic hardening behavior on the shakedown behaviors of structure has been investigated by performing shakedown analysis for some specific problems. The results obtained only show that the shakedown limit loads of structures with kinematic hardening model are larger than or equal to those with perfectly plastic model of the same initial yield stress. To further investigate the rules governing the different shakedown behaviors of kinematic hardening structures, the extended shakedown theorem for limited kinematic hardening is applied, the shakedown condition is then proposed, and a general analytical solution for the structural shakedown limit load is thus derived. The analytical shakedown limit loads for fully reversed cyclic loading and non-fully reversed cyclic loading are then given based on the general solution. The resulting analytical solution is applied to some specific problems: a hollow specimen subjected to tension and torsion, a flanged pipe subjected to pressure and axial force and a square plate with small central hole subjected to biaxial tension. The results obtained are compared with those in literatures, they are consistent with each other. Based on the resulting general analytical solution, rules governing the general effects of kinematic hardening behavior on the shakedown behavior of structure are clearly.



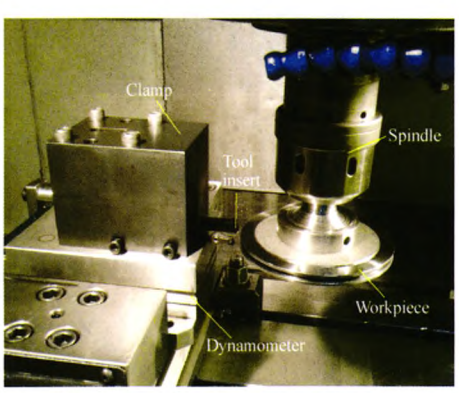
(a) Short anode nozzle

(b) Long anode nozzle

DOI: 10.3901/CJME.2016.0503.064

Effects of the Nozzle Design on the Properties of Plasma Jet and Formation of YSZ Coatings under Low Pressure Conditions. SUN Chengqi, GAO Yang, YANG Deming, and FU Yingqing

Abstract: How to control the quality of the coatings has become a major problem during the plasma spraying. Because nozzle contour has a great influence on the characteristic of the plasma jet, two kinds of plasma torches equipped with a standard cylindrical nozzle and a converging-diverging nozzle are designed for low pressure plasma spraying(LPPS) and very low pressure plasma spraying(VLPPS). Yttria stabilized zirconia(YSZ) coatings are obtained in the reducing pressure environment. The properties of the plasma jet without or with powder injection are analyzed by optical emission spectroscopy, and the electron temperature is calculated based on the ratio of the relative intensity of two Arlspectral lines. The results show that some of the YSZ powder can be vaporized in the low pressure enlarged plasma jet, and the long anode nozzle may improve the characteristics of the plasma jet. The coatings deposited by LPPS are mainly composed of the equiaxed grains and while the unmelted powder particles and large scalar pores appear in the coatings made by VLPPS. The long anode nozzle could improve the melting of the powders and deposition efficiency, and enhance the coatings' hardness. At the same time, the long anode nozzle could lead to a decrease in the overspray phenomenon. Through the comparison of the two different size's nozzle, the long anode is much more suitable for making the YSZ coatings.



DOI: 10.3901/CJME.2016.0406.046

Constitutive Modeling for Ti-6Al-4V Alloy Machining Based on the SHPB Tests and Simulation. CHEN Guang, KE Zhihong, REN Chengzu, and LI Jun

Abstract: A constitutive model is critical for the prediction accuracy of a metal cutting simulation. The highest strain rate involved in the cutting process can be in the range of 10^4–10^6 s^{-1}. Flow stresses at high strain rates are close to that of cutting are difficult to test via experiments. Split Hopkinson compression bar (SHPB) technology is used to study the deformation behavior of Ti-6Al-4V alloy at strain rates of 10^{-4}–$10^4 s^{-1}$. The Johnson Cook (JC) model was applied to characterize the flow stresses of the SHPB tests at various conditions. The parameters of the JC model are optimized by using a genetic algorithm technology. The JC plastic model and the energy density-based ductile failure criteria are adopted in the proposed SHPB finite element simulation model. The simulated flow stresses and the failure characteristics, such as the cracks along the adiabatic shear bands agree well with the experimental results. Afterwards, the SHPB simulation is used to simulate higher strain rate(approximately 3×10^4 s^{-1}) conditions by minimizing the size of the specimen. The JC model parameters covering higher strain rate conditions which are close to the deformation condition in cutting were calculated based on the flow stresses obtained by using the SHPB tests (10^{-4}–10^4 s^{-1}) and simulation (up to 3×10^4 s^{-1}). The cutting simulation using the constitutive parameters is validated by the measured forces and chip morphology. The constitutive model and parameters for high strain rate conditions that are identical to those of cutting were obtained based on the SHPB tests and simulation.

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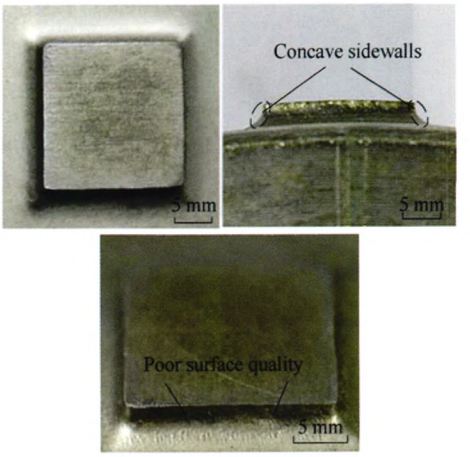
Vol. 29, No. 5, 2016

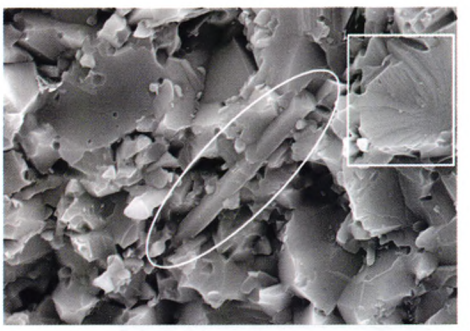
DOI: 10.3901/CJME.2016.0419.055

Abstract: Electrochemical machining (ECM) has been widely used in the aerospace, automotive, defense and medical industries for its many advantages over traditional machining methods. However, the machining accuracy in ECM is to a great extent limited by the stray corrosion of the unwanted material removal. Many attempts have been made to improve the ECM accuracy, such as the use of a pulse power, passivating electrolytes and auxiliary electrodes. However, they are sometimes insufficient for the reduction of the stray removal and have their limitations in many cases. To solve the stray corrosion problem in CRECM, insulating and conductive coatings are respectively used. The different implement processes of the two kinds of coatings are introduced. The effects of the two kinds of shielding coatings on the anode shaping process are investigated. Numerical simulations and experiments are conducted for the comparison of the two coatings. The simulation and experimental results show that both the two kinds of coatings are valid for the reduction of stray corrosion on the top surface of the convex structure. However, for insulating coating, the convex sidewall becomes concave when the height of the convex structure is over 1.26 mm. In addition, it is easy to peel off by the high-speed electrolyte. In contrast, the conductive coating has a strong adhesion, and can be well reserved during the whole machining process. The convex structure fabricated by using a conductive iron coating layer presents a favorable sidewall profile. It is concluded that the conductive coating is more effective for the improvement of the machining quality in CRECM. The proposed shielding coatings can also be employed to reduce the stray corrosion in other schemes of ECM.



DOI: 10.3901/CJME.2016.0411.049

Abstract: In recent decades, many additives with different characteristics have been applied to strengthen and toughen Al_2O_3-based ceramic cutting tool materials. Among them, SiC whiskers and SiC nanoparticles showed excellent performance in improving the material properties. While no attempts have been made to add SiC whiskers and SiC nanoparticles together into the ceramic matrix and the synergistically toughening effects of them have not been studied. An Al_2O_3-SiC_w-SiC_{np} advanced ceramic cutting tool material is fabricated by adding both one-dimensional SiC whiskers and zero-dimensional SiC nanoparticles into the Al_2O_3 matrix with an effective dispersing and mixing process. The composites with 25 vol% SiC whiskers and 25 vol% SiC nanoparticles alone are also investegated for comparison purposes. Results show that the Al_2O_3-SiC_w-SiC_{np} composite with both 20 vol% SiC whiskers and 5 vol% SiC nanoparticles additives have much improved mechanical properties. The flexural strength of Al_2O_3-SiC_w-SiC_{np} is 730±95 MPa and fracture toughness is 5.6±0.6 MPa·$m^{1/2}$. The toughening and strengthening mechanisms of SiC whiskers and nanoparticles are studied when they are added either individually or in combination. It is indicated that when SiC whiskers and nanoparticles are added together, the grains are further refined and homogenized, so that the microstructure and fracture mode ratio is modified. The SiC nanoparticles are found helpful to enhance the toughening effects of the SiC whiskers. The proposed research helps to enrich the types of ceramic cutting tool and is benefit to expand the application range of ceramic cutting tool.



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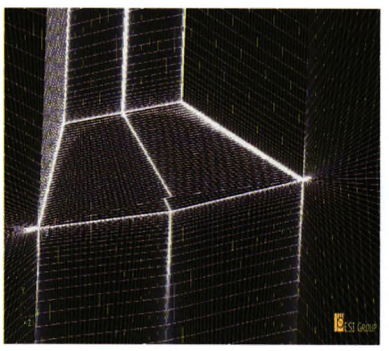
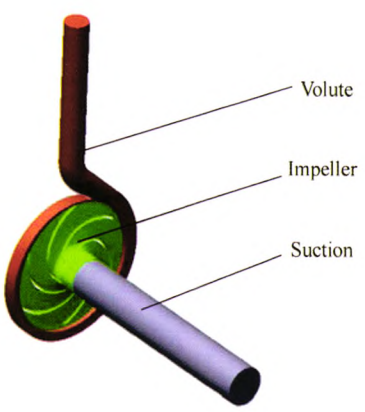


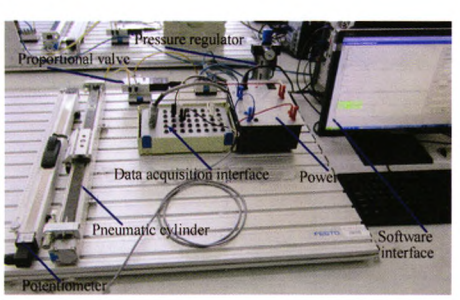
DOI: 10.3901/CJME.2016.0128.016

Abstract: Reduced order models(ROMs) based on the snapshots on the CFD high-fidelity simulations have been paid great attention recently due to their capability of capturing the features of the complex geometries and flow configurations. To improve the efficiency and precision of the ROMs, it is indispensable to add extra sampling points to the initial snapshots, since the number of sampling points to achieve an adequately accurate ROM is generally unknown in prior, but a large number of initial sampling points reduces the parsimony of the ROMs. A fuzzy-clustering-based adding-point strategy is proposed and the fuzzy clustering acts an indicator of the region in which the precision of ROMs is relatively low. The proposed method is applied to construct the ROMs for the benchmark mathematical examples and a numerical example of hypersonic aerothermodynamics prediction for a typical control surface. The proposed method can achieve a 34.5% improvement on the efficiency than the estimated mean squared error prediction algorithm and shows same-level prediction accuracy.



DOI: 10.3901/CJME.2016.0519.069

Abstract: In order to widen the high-efficiency operating range of a low-specific-speed centrifugal pump , an optimization process for considering efficiencies under $1.0Q_d$ and $1.4Q_d$ is proposed. Three parameters, namely, the blade outlet width b_2, blade outlet angle β_2, and blade wrap angle φ, are selected as design variables. Impellers are generated using the optimal Latin hypercube sampling method. The pump efficiencies are calculated using the software CFX 14.5 at two operating points selected as objectives. Surrogate models are also constructed to analyze the relationship between the objectives and the design variables. Finally, the particle swarm optimization algorithm is applied to calculate the surrogate model to determine the best combination of the impeller parameters. The results show that the performance curve predicted by numerical simulation has a good agreement with the experimental results. Compared with the efficiencies of the original impeller, the hydraulic efficiencies of the optimized impeller are increased by 4.18% and 0.62% under $1.0Q_d$ and $1.4Q_d$, respectively. The comparison of inner flow between the original pump and optimized one illustrates the improvement of performance. The optimization process can provide a useful reference on performance improvement of other pumps, even on reduction of pressure fluctuations.



DOI: 10.3901/CJME.2016.0412.050

Abstract: With the price decreasing of the pneumatic proportional valve and the high performance micro controller, the simple structure and high tracking performance pneumatic servo system demonstrates more application potential in many fields. However, most existing control methods with high tracking performance need to know the model information and to use pressure sensor. This limits the application of the pneumatic servo system. An adaptive backstepping slide mode control method is proposed for pneumatic position servo system. The proposed method designs adaptive slide mode controller using backstepping design technique. The controller parameter adaptive law is derived from Lyapunov analysis to guarantee the stability of the system. A theorem is testified to show that the state of closed-loop system is uniformly bounded, and the closed-loop system is stable. The advantages of the proposed method include that system dynamic model parameters are not required for the controller design, uncertain parameters bounds are not need, and the bulk and expensive pressure sensor is not needed as well. Experimental results show that the designed controller can achieve better tracking performance, as compared with some existing methods.

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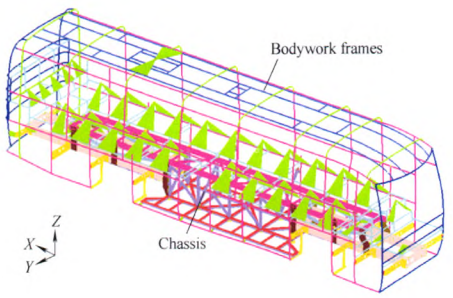
Vol. 29, No. 5, 2016

DOI: 10.3901/CJME.2016.0801.086

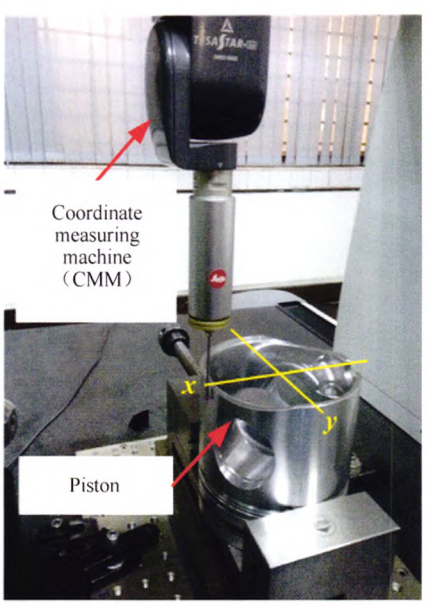
Abstract: For the coach industry, rapid modeling and efficient optimization methods are desirable for structure modeling and optimization based on simplified structures, especially for use early in the concept phase and with capabilities of accurately expressing the mechanical properties of structure and with flexible section forms. However, the present dimension-based methods cannot easily meet these requirements. To achieve these goals, the property-based modeling (PBM) beam modeling method is studied based on the PBM theory and in conjunction with the characteristics of coach structure of taking beam as the main component. For a beam component of concrete length, its mechanical characteristics are primarily affected by the section properties. Four section parameters are adopted to describe the mechanical properties of a beam, including the section area, the principal moments of inertia about the two principal axles, and the torsion constant of the section. Based on the equivalent stiffness strategy, expressions for the above section parameters are derived, and the PBM beam element is implemented in HyperMesh software. A case is realized using this method, in which the structure of a passenger coach is simplified. The model precision is validated by comparing the basic performance of the total structure with that of the original structure, including the bending and torsion stiffness and the first-order bending and torsional modal frequencies. Sensitivity analysis is conducted to choose design variables. The optimal Latin hypercube experiment design is adopted to sample the test points, and polynomial response surfaces are used to fit these points. To improve the bending and torsion stiffness and the first-order torsional frequency and taking the allowable maximum stresses of the braking and left turning conditions as constraints, the multi-objective optimization of the structure is conducted using the NSGA-II genetic algorithm on the ISIGHT platform. The result of the Pareto solution set is acquired, and the selection strategy of the final solution is discussed. The case study demonstrates that the mechanical performances of the structure can be well-modeled and simulated by PBM beam. Because of the merits of fewer parameters and convenience of use, this method is suitable to be applied in the concept stage. Another merit is that the optimization results are the requirements for the mechanical performance of the beam section instead of those of the shape and dimensions, bringing flexibility to the succeeding design.



Precision Measurement and Signal Processing

DOI: 10.3901/CJME.2016.0205.022

Abstract: To improve the measurement and evaluation of form error of an elliptic section, an evaluation method based on least squares fitting is investigated to analyze the form and profile errors of an ellipse using coordinate data. Two error indicators for defining ellipticity are discussed, namely the form error and the profile error, and the difference between both is considered as the main parameter for evaluating machining quality of surface and profile. Because the form error and the profile error rely on different evaluation benchmarks, the major axis and the foci rather than the centre of an ellipse are used as the evaluation benchmarks and can accurately evaluate a tolerance range with the separated form error and profile error of workpiece. Additionally, an evaluation program based on the LS model is developed to extract the form error and the profile error of the elliptic section, which is well suited for separating the two errors by a standard program. Finally, the evaluation method about the form and profile errors of the ellipse is applied to the measurement of skirt line of the piston, and results indicate the effectiveness of the evaluation. This approach provides the new evaluation indicators for the measurement of form and profile errors of ellipse, which is found to have better accuracy and can thus be used to solve the difficult of the measurement and evaluation of the piston in industrial production.



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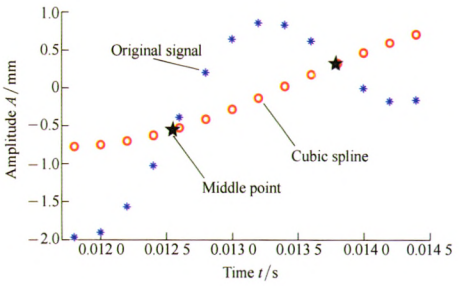
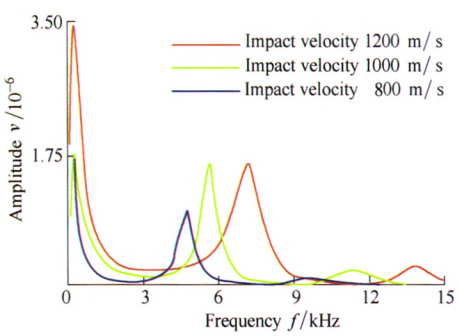


DOI: 10.3901/CJME.2015.1106.132

Abstract: The vibration signal contains a wealth of sensitive information which reflects the running status of the equipment. It is one of the most important steps for precise diagnosis to decompose the signal and extracts the effective information properly. The traditional classical adaptive signal decomposition method, such as EMD, exists the problems of mode mixing, low decomposition accuracy etc. Aiming at those problems, EAED(extreme average envelope decomposition) method is presented based on EMD. EAED method has three advantages. Firstly, it is completed through midpoint envelopment method rather than using maximum and minimum envelopment respectively as used in EMD. Therefore, the average variability of the signal can be described accurately. Secondly, in order to reduce the envelope errors during the signal decomposition, replacing two envelopes with one envelope strategy is presented. Thirdly, the similar triangle principle is utilized to calculate the time of extreme average points accurately. Thus, the influence of sampling frequency on the calculation results can be significantly reduced. Experimental results show that EAED could separate out single frequency components from a complex signal gradually. EAED could not only isolate three kinds of typical bearing fault characteristic of vibration frequency components but also has fewer decomposition layers. EAED replaces quadratic enveloping to an envelope which ensuring to isolate the fault characteristic frequency under the condition of less decomposition layers. Therefore, the precision of signal decomposition is improved.



DOI: 10.3901/CJME.2016.0616.073

Abstract: In hard target penetration simulation, the existing researches of the convergence of results are mainly concentrating in the corresponding relationship between penetration depth and mesh scales. However, the influence of the mesh difference on the penetration resistance and acceleration signals are seldom refer to. This paper presents the occurring mechanism and restraining method of numerical noise signal in penetration simulation. First, the concept of the noise signal izs proposed. By taking a 3D penetration simulation as example, the influence of the noise signal on the penetration resistance in different mesh scales and impact velocity is studied. To ensure the convergence of the computational results, the grid scale of the target is encrypted to 1:1:8. In addition, modern spectrum analysis method is introduced to further analyze the penetration resistance signal. The research results presented is useful to improve the computational accuracy of high speed projectile penetration simulation, and provide important reference for carrying out structural design and optimization of fuze system.

CHINESE JOURNAL OF MECHANICAL ENGINEERING

中国机械工程学报

(Bimonthly, Started in 1988)

Vol. 29, No. 5, September 2016

Responsible Department China Association for Science and Technology

Sponsored by Chinese Mechanical Engineering Society

Associated to IFToMM

Edited by Editorial Office of Chinese Journal of Mechanical Engineering
Address: 22 Baiwanzhuang Dajie, Beijing 100037, China
Tel: +86-10-88379909
Fax: +86-10-68994557
http: //www.cjmenet.com
E-mail: cjme@cmes.org

Printed by Beijing BOHS Colour Printing Co., Ltd.

Subscriptions in China Subscriptions are available at post offices throughout China
Postal Code: 2-377
Subscription Price in China: ¥ 100

Coverage in Abstracting & Indexing (A&I) Services: Science Citation Index Expanded (SciSearch), Journal Citation Reports/ Science Edition, SCOPUS, INSPEC, Zentralblatt Math, Chemical Abstracts Service (CAS), Google Scholar, CSA, Chinese Science Citation Database, Earthquake Engineering Abstracts, EI-Compendex, OCLC, SCImago, Summon by ProQuest

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ISSN 1000-9345

CN 11-2187/TH