CHINESE JOURNAL OF MECHANICAL ENGINEERING®

中国机械工程学报
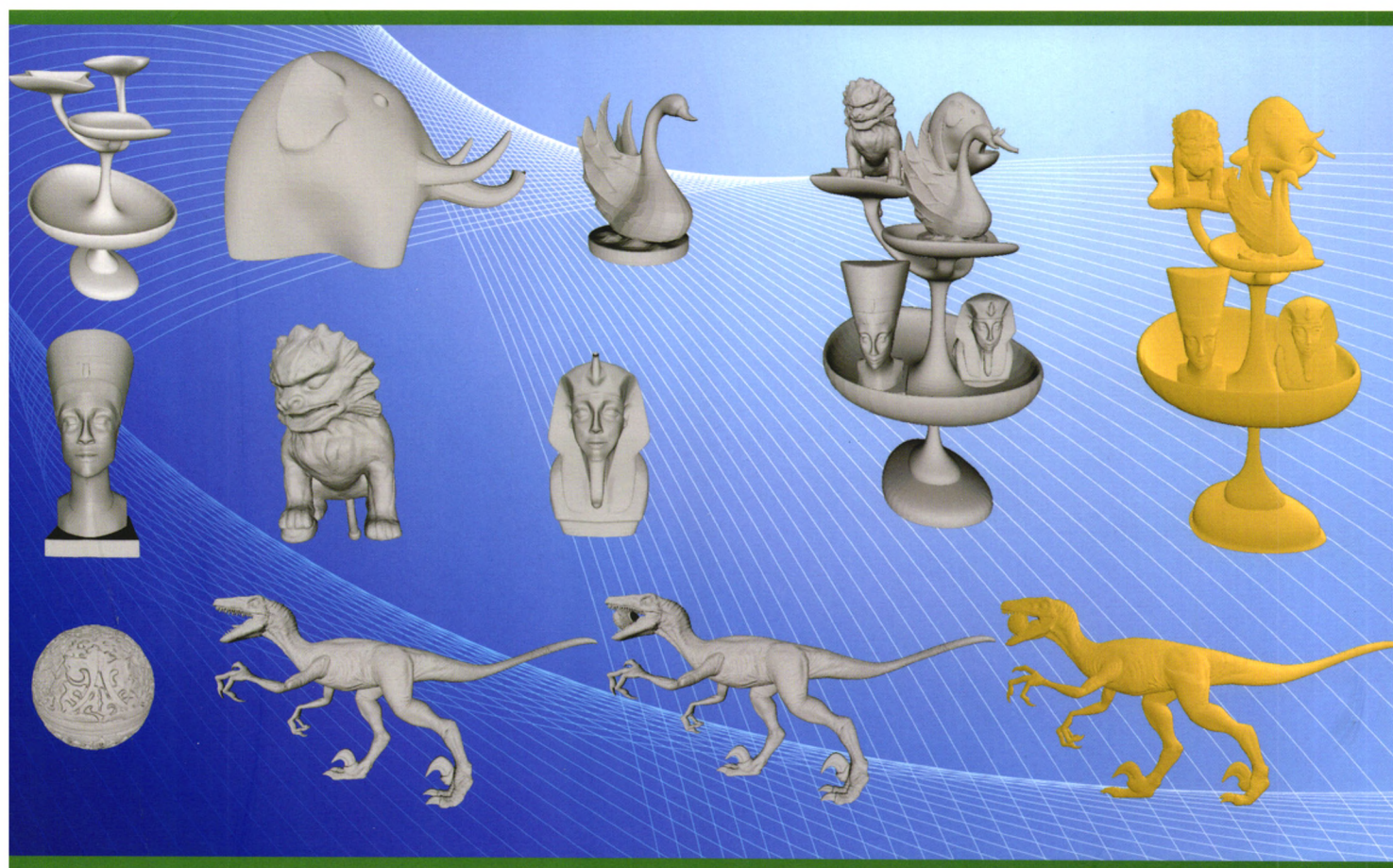
CHINESE JOURNAL OF MECHANICAL ENGINEERING

Editorial

Future Digital Design and Manufacturing

Abstract: The fourth industrial revolution promises to create what has been called the smart factory. The vision is that within such modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralised decisions. This paper provides a view of this initiative from an automation systems perspective. In this context it considers how future automation systems might be effectively configured and supported through their lifecycles and how integration, application modelling, visualisation and reuse of such systems might be best achieved. The paper briefly describes limitations in current engineering methods, and new emerging approaches including the cyber physical systems (CPS) engineering tools being developed by the automation systems group (ASG) at Warwick Manufacturing Group, University of Warwick, UK.
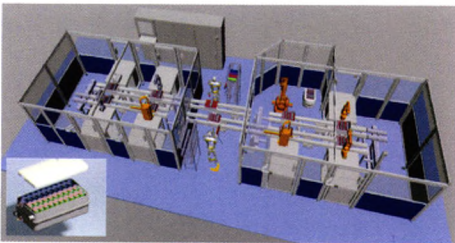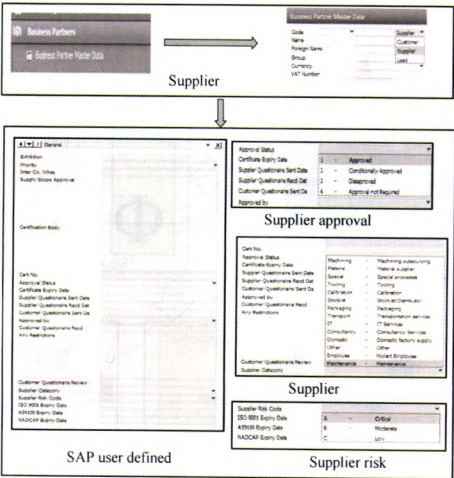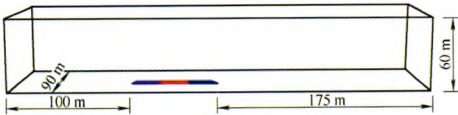
Abstract: Crowdsourcing is an innovative business practice of obtaining needed services, ideas, or content or even funds by soliciting contributions from a large group of people (the 'Crowd'). The potential benefits of utilizing crowdsourcing in product design are well-documented, but little research exists on what are the barriers and opportunities in adopting crowdsourcing in new product development (NPD) of manufacturing SMEs. In order to answer the above questions, a Proof of Market study is carried out on crowdsourcing-based product design under an Innovate UK funded Smart project, which aims at identifying the needs, challenges and future development opportunities associated with adopting crowdsourcing strategies for NPD. The research findings from this study are reported here and can be used to guide future development of crowdsourcing-based collaborative design methods and tools and provide some practical references for industry to adopt this new and emerging collaborative design method in their business.
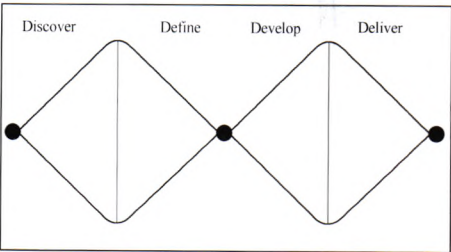
Abstract: Aerospace manufacturing SMEs are continuously facing the challenge on managing their supply chain and complying with the aerospace manufacturing quality standard requirement due to their lack of resources and the nature of business. In this paper, the ERP system based approach is presented to quality control and assurance work in light of seamless integration of in-process production data and information internally and therefore managing suppliers more effectively and efficiently. The Aerospace Manufacturing Quality Assurance Standard (BS/EN9100) is one of the most recognised and essential protocols for developing the industry-operated-and-driven quality assurance systems. The research investigates using the ERP based system as an enabler to implement BS/EN9100 quality management system at manufacturing SMEs and the associated implementation and application perspectives. An application case study on a manufacturing SME is presented by using the SAP based implementation, which helps further evaluate and validate the approach and application system development.

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Abstract: When designing a complex mechatronics system, such as high speed trains, it is relatively difficult to effectively simulate the entire system's dynamic behaviors because it involves multi-disciplinary subsystems. Currently，a most practical approach for multi-disciplinary simulation is interface based coupling simulation method, but it faces a twofold challenge: spatial and time unsynchronizations among multi-directional coupling simulation of subsystems. A new collaborative simulation method with spatiotemporal synchronization process control is proposed for coupling simulating a given complex mechatronics system across multiple subsystems on different platforms. The method consists of 1) a coupler-based coupling mechanisms to define the interfacing and interaction mechanisms among subsystems, and 2) a simulation process control algorithm to realize the coupling simulation in a spatiotemporal synchronized manner. The test results from a case study show that the proposed method 1) can certainly be used to simulate the sub-systems interactions under different simulation conditions in an engineering system, and 2) effectively supports multi-directional coupling simulation among multi-disciplinary subsystems. This method has been successfully applied in China high speed train design and development processes, demonstrating that it can be applied in a wide range of engineering systems design and simulation with improved efficiency and effectiveness.
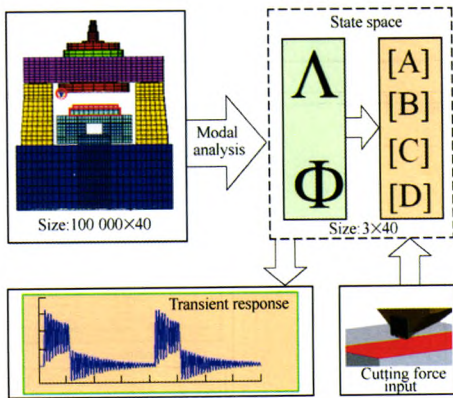
Abstract: As energy efficiency is one of the key essentials towards sustainability, the development of an energy-resource efficient manufacturing system is among the great challenges facing the current industry. Meanwhile, the availability of advanced technological innovation has created more complex manufacturing systems that involve a large variety of processes and machines serving different functions. To extend the limited knowledge on energy-efficient scheduling, the research presented in this paper attempts to model the production schedule at an operation process by considering the balance of energy consumption reduction in production, production work flow (productivity) and quality. An innovative systematic approach to manufacturing energy-resource efficiency is proposed with the virtual simulation as a predictive modelling enabler, which provides real-time manufacturing monitoring, virtual displays and decision-makings and consequentially an analytical and multidimensional correlation analysis on interdependent relationships among energy consumption, work flow and quality errors. The regression analysis results demonstrate positive relationships between the work flow and quality errors and the work flow and energy consumption. When production scheduling is controlled through optimization of work flow, quality errors and overall energy consumption, the energy-resource efficiency can be achieved in the production. Together, this proposed multidimensional modelling and analysis approach provides optimal conditions for the production scheduling at the manufacturing system by taking account of production quality, energy consumption and resource efficiency, which can lead to the key competitive advantages and sustainability of the system operations in the industry.
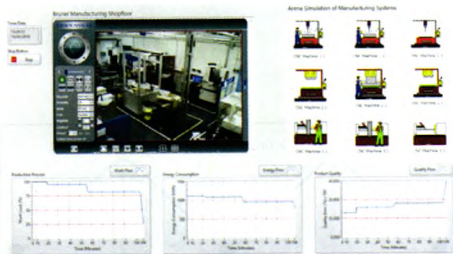
Abstract: The interaction between the machining process and the machine tool (IMPMT) plays an important role on high precision components manufacturing. However, most researches are focused on the machining process or the machine tool separately, and the interaction between them has been always overlooked. In this paper, a novel simplified method is proposed to realize the simulation of IMPMT by combining use the finite element method and state space method. In this method, the transfer function of the machine tool is built as a small state space. The small state space is obtained from the complicated finite element model of the whole machine tool. Furthermore, the control system of the machine tool is integrated with the transfer function of the machine tool to generate the cutting trajectory. Then, the tool tip response under the cutting force is used to predict the machined surface. Finally, a case study is carried out for a fly-cutting machining process, the dynamic response analysis of an ultra-precision fly-cutting machine tool and the machined surface verifies the effectiveness of this method. This research proposes a simplified method to study the IMPMT, the relationships between the machining process and the machine tool are established and the surface generation is obtained.

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Abstract: Most of the previous studies on the vibration ride comfort of the human-vehicle system were focused only on one or two aspects of the investigation. A hybrid approach which integrates all kinds of investigation methods in real environment and virtual environment is described. The real experimental environment includes the WBV(whole body vibration) test, questionnaires for human subjective sensation and motion capture. The virtual experimental environment includes the theoretical calculation on simplified 5-DOF human body vibration model, the vibration simulation and analysis within ADAMS/Vibration™ module, and the digital human biomechanics and occupational health analysis in Jack software. While the real experimental environment provides realistic and accurate test results, it also serves as core and validation for the virtual experimental environment. The virtual experimental environment takes full advantages of current available vibration simulation and digital human modelling software, and makes it possible to evaluate the sitting posture comfort in a human-vehicle system with various human anthropometric parameters. How this digital evaluation system for car seat comfort design is fitted in the Industry 4.0 framework is also proposed.

Abstract: In order to find better simplicity measurements for 3D object recognition, a new set of local regularities is developed and tested in a stepwise 3D reconstruction method, including localized minimizing standard deviation of angles(L-MSDA), localized minimizing standard deviation of segment magnitudes(L-MSDSM), localized minimum standard deviation of areas of child faces (L-MSDAF), localized minimum sum of segment magnitudes of common edges (L-MSSM), and localized minimum sum of areas of child face (L-MSAF). Based on their effectiveness measurements in terms of form and size distortions, it is found that when two local regularities: L-MSDA and L-MSDSM are combined together, they can produce better performance. In addition, the best weightings for them to work together are identified as 10% for L-MSDSM and 90% for L-MSDA. The test results show that the combined usage of L-MSDA and L-MSDSM with identified weightings has a potential to be applied in other optimization based 3D recognition methods to improve their efficacy and robustness.
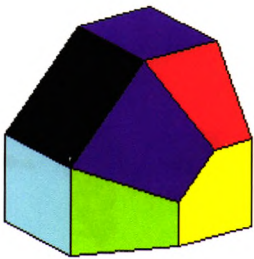
Abstract: Thermal conductivity is one of key parameters of adsorbents, which will affect the overall system performance of adsorption chiller. To improve adsorbent's thermal conductivity is always one of research focuses in chemisorption field. A new chemical composite adsorbent is fabricated by adding carbon coated metal(Aluminum and Nickel) nanoparticles with three different addition amounts into the mixture of chloride salts and natural expanded graphite aiming to improve the thermal conductivity. The preparation processes and its thermal conductivity of this novel composite adsorbent are reported and summarized. Experimental results indicate that the nanoparticles are homogenously dispersed in the composite adsorbent by applying the reported preparation processes. The thermal conductivity of the composite adsorbent can averagely enlarge by 20% when the weight ratio of the added nanoparticles is 10 wt%. Moreover, carbon coated aluminum nanoparticles exhibit more effective enlargement in thermal conductivity than nickel nanoparticles. As for the composite adsorbent of $CaCl_2$-NEG, there is a big reinforcement from 30% to 50% for Al@C nanoparticles, however only 10% in maximum caused by Ni@C nanoparticles. The proposed research provides a methodology to design and prepare thermal conductive chemical composite adsorbent.
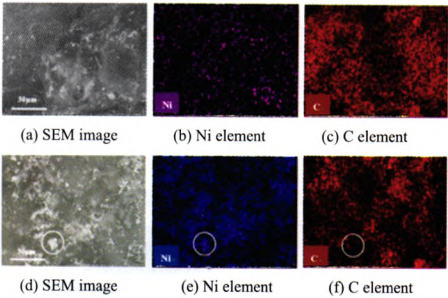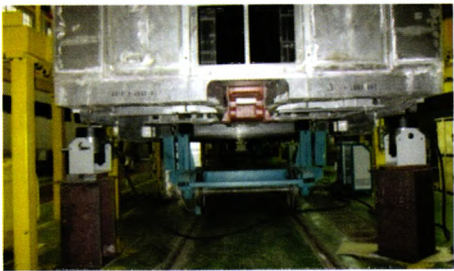
(a) SEM image   (b) Ni element   (c) C element

(d) SEM image   (e) Ni element   (f) C element

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Abstract: Finite element analysis(FEA) and modal test are main methods to give the first-order vertical bending vibration frequency of train carbody at present, but they are inefficiency and waste plenty of time. Based on Timoshenko beam theory, the bending deformation, moment of inertia and shear deformation are considered. Carbody is divided into some parts with the same length, and it's stiffness is calculated with series principle, it's cross section area, moment of inertia and shear shape coefficient is equivalent by segment length, and the fimal corrected first-order vertical bending vibration frequency analytical formula is deduced. There are 6 simple carbodies and 1 real carbody as examples to test the formula, all analysis frequencies are very close to their FEA frequencies, and especially for the real carbody, the error between analysis and experiment frequency is 0.75%. Based on the analytic formula, sensitivity analysis of the real carbody's design parameters is done, and some main parameters are found. The series principle of carbody stiffness is introduced into Timoshenko beam theory to deduce a formula, which can estimate the first-order vertical bending vibration frequency of carbody quickly without traditional FEA method and provide a reference to design engineers.

Abstract: It is difficult to extend image-based relief generation to high-relief generation, as the images contain insufficient height information. To generate reliefs from three-dimensional (3D) models, it is necessary to extract the height fields from the model, but this can only generate bas-reliefs. To overcome this problem, an efficient method is proposed to generate bas-reliefs and high-reliefs directly from 3D meshes. To produce relief features that are visually appropriate, the 3D meshes are first scaled. 3D unsharp masking is used to enhance the visual features in the 3D mesh, and average smoothing and Laplacian smoothing are implemented to achieve better smoothing results. A nonlinear variable scaling scheme is then employed to generate the final bas-reliefs and high-reliefs. Using the proposed method, relief models can be generated from arbitrary viewing positions with different gestures and combinations of multiple 3D models. The generated relief models can be printed by 3D printers. The proposed method provides a means of generating both high-reliefs and bas-reliefs in an efficient and effective way under the appropriate scaling factors.

Abstract: The use of pan-ethnic-group products form knowledge primarily depends on a designer's subjective experience without user participation. The majority of studies primarily focus on the detection of the perceptual demands of consumers from the target product category. A pan-ethnic-group products form gene clustering method based on emotional semantic is constructed. Consumers' perceptual images of the pan-ethnic-group products are obtained by means of product form gene extraction and coding and computer aided product form clustering technology. A case of form gene clustering about the typical pan-ethnic-group products is investigated which indicates that the method is feasible. This paper opens up a new direction for the future development of product form design which improves the agility of product design process in the era of Industry 4.0.
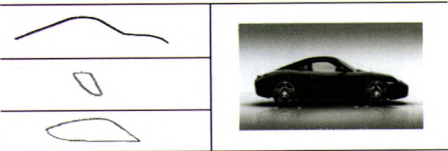
Wireless Device Connection Problems and Design Solutions. SONG Ji-Won, NORMAN Donald, NAM Tek-Jin, and QIN Shengfeng

Abstract: Users, especially the non-expert users, commonly experience problems when connecting multiple devices with interoperability. While studies on multiple device connections are mostly concentrated on spontaneous device association techniques with a focus on security aspects, the research on user interaction for device connection is still limited. More research into understanding people is needed for designers to devise usable techniques. This research applies the Research-through-Design method and studies the non-expert users' interactions in establishing wireless connections between devices. The "Learning from Examples" concept is adopted to develop a study focus line by learning from the expert users' interaction with devices. This focus line is then used for guiding researchers to explore the non-expert users' difficulties at each stage of the focus line. Finally, the Research-through-Design approach is used to understand the users' difficulties, gain insights to design problems and suggest usable solutions. When connecting a device, the user is required to manage not only the device's functionality but also the interaction between devices. Based on learning from failures, an important insight is found that the existing design approach to improve single-device interaction issues, such as improvements to graphical user interfaces or computer guidance, cannot help users to handle problems between multiple devices. This study finally proposes a desirable user-device interaction in which images of two devices function together with a system image to provide the user with feedback on the status of the connection, which allows them to infer any required actions.

Robotics

Description of a Propulsion Unit Used in Guiding a Walking Machine by Recognizing a Three-point Bordered Path. NÚÑEZ-ALTAMIRANO Diego A, JUÁREZ-CAMPOS Ignacio, MÁRQUEZ-PÉREZ Lucia, and FLORES-DÍAZ Ociel

Abstract: A reconfigurable propulsion unit based on the Peaucellier-Lipkin mechanism has the ability to describe exact straight or curved paths depending on the selected ratio between the lengths of two of its links. The Peaucellier-Lipkin mechanism with one degree of freedom is transformed into a more sophisticated parallel kinematic chain by including four more degrees of freedom. The resulting propulsion unit is able to adapt its kinematic structure and reach instant centers of rotation, in accordance with the presence of three points that border a geometric path. A laser sensor mounted on the body of the machine detects each point. Once the machine has detected the exact location of the border of the road, it walks along a curve parallel to that border. Although the proposed research describes only one propulsion unit or leg, the methodology can be applied to all the legs of the walking machine. The novel 5-DOF leg is able to reach different centers of rotation, providing either the concave or convex arcs that satisfy the basic principle of displacement of walking machines.
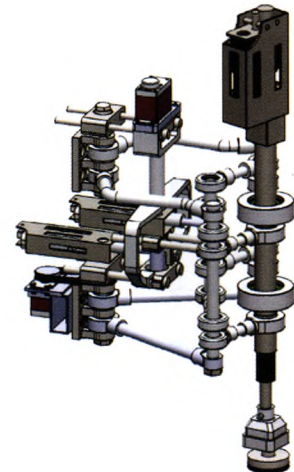
Dynamic Soft Tissue Deformation Estimation Based on Energy Analysis. GAO Dedong, LEI Yong, and YAO Bin

Abstract: The needle placement accuracy of millimeters is required in many needle-based surgeries. The tissue deformation, especially that occurring on the surface of organ tissue, affects the needle-targeting accuracy of both manual and robotic needle insertions. It is necessary to understand the mechanism of tissue deformation during needle insertion into soft tissue. In this paper, soft tissue surface deformation is investigated on the basis of continuum mechanics, where a geometry model is presented to quantitatively approximate the volume of tissue deformation. The energy-based method is presented to the dynamic process of needle insertion into soft tissue based on continuum mechanics, and the volume of the cone is exploited to quantitatively approximate the deformation on the surface of soft tissue. The external work is converted into potential, kinetic, dissipated, and strain energies during the dynamic rigid needle-tissue interactive process. The needle insertion experimental setup, consisting of a linear actuator, force sensor, needle, tissue container, and a light, is constructed while an image-based method for measuring the depth and radius of the soft tissue surface deformations is introduced to obtain the experimental data. The relationship between the changed volume of tissue deformation and the insertion parameters is created based on the law of conservation of energy, with the volume of tissue deformation having been obtained using image-based measurements. The experiments are performed on phantom specimens, and an energy-based analytical fitted model is presented to estimate the volume of tissue deformation. The experimental results show that the energy-based analytical fitted model can predict the volume of soft tissue deformation, and the root mean squared errors of the fitting model and experimental data are 0.61 and 0.25 at the velocities 2.50 mm/s and 5.00 mm/s. The estimating parameters of the soft tissue surface deformations are proven to be useful for compensating the needle-targeting error in the rigid needle insertion procedure, especially for percutaneous needle insertion into organs.
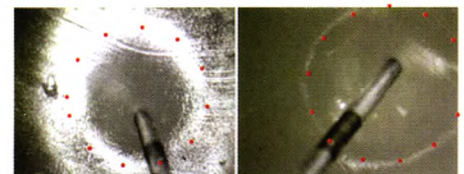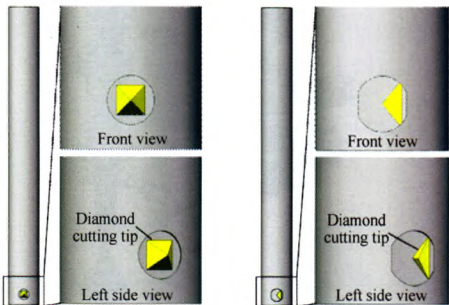
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Vol. 29, No. 6, 2016

Abstract: Dynamic modeling of a parallel manipulator(PM) is an important issue. A complete PM system is actually composed of multiple physical domains. As PMs are widely used in various fields, the importance of modeling the global dynamic model of the PM system becomes increasingly prominent. Currently there lacks further research in global dynamic modeling. A unified modeling approach for the multi-energy domains PM system is proposed based on bond graph and a global dynamic model of the 3-UPS/S parallel stabilized platform involving mechanical and electrical-hydraulic elements is built. Firstly, the screw bond graph theory is improved based on the screw theory, the modular joint model is modeled and the normalized dynamic model of the mechanism is established. Secondly, combined with the electro-hydraulic servo system model built by traditional bond graph, the global dynamic model of the system is obtained, and then the motion, force and power of any element can be obtained directly. Lastly, the experiments and simulations of the driving forces, pressure and flow are performed, and the results show that, the theoretical calculation results of the driving forces are in accord with the experimental ones, and the pressure and flow of the first limb and the third limb are symmetry with each other. The results are reasonable and verify the correctness and effectiveness of the model and the method. The proposed dynamic modeling method provides a reference for modeling of other multi-energy domains system which contains complex PM.
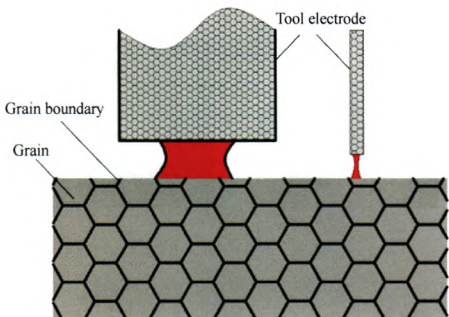
Advanced Maching

Abstract: Tailored surface textures at the micro- or nanoscale dimensions are widely used to get required functional performances. Rotary ultrasonic texturing (RUT) technique has been proved to be capable of fabricating periodic micro- and nanostructures. In the present study, diamond tools with geometrically defined cutting edges were designed for fabricating different types of tailored surface textures using the RUT method. Surface generation mechanisms and machinable structures of the RUT process are analyzed and simulated with a 3D-CAD program. Textured surfaces generated by using a triangular pyramid cutting tip are constructed. Different textural patterns from several micrometers to several tens of micrometers with few burrs were successfully fabricated, which proved that tools with a proper two-rake-face design are capable of removing cutting chips efficiently along a sinusoidal cutting locus in the RUT process. Technical applications of the textured surfaces are also discussed. Wetting properties of textured aluminum surfaces were evaluated by combining the test of surface roughness features. The results show that the real surface area of the textured aluminum surfaces almost doubled by comparing with that of a flat surface, and anisotropic wetting properties were obtained due to the obvious directional textural features.
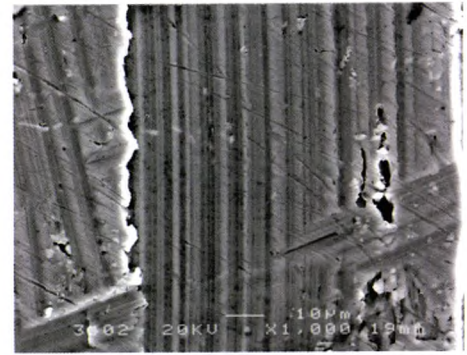
Abstract: Electrical discharge machining(EDM) is a promising non-traditional micro machining technology that offers a vast array of applications in the manufacturing industry. However, scale effects occur when machining at the micro-scale, which can make it difficult to predict and optimize the machining performances of micro EDM. A new concept of "scale effects" in micro EDM is proposed, the scale effects can reveal the difference in machining performances between micro EDM and conventional macro EDM. Similarity theory is presented to evaluate the scale effects in micro EDM. Single factor experiments are conducted and the experimental results are analyzed by discussing the similarity difference and similarity precision. The results show that the output results of scale effects in micro EDM do not change linearly with discharge parameters. The values of similarity precision of machining time significantly increase when scaling-down the capacitance or open-circuit voltage. It is indicated that the lower the scale of the discharge parameter, the greater the deviation of non-geometrical similarity degree over geometrical similarity degree, which means that the micro EDM system with lower discharge energy experiences more scale effects. The largest similarity difference is 5.34 while the largest similarity precision can be as high as 114.03. It is suggested that the similarity precision is more effective in reflecting the scale effects and their fluctuation than similarity difference. Consequently, similarity theory is suitable for evaluating the scale effects in micro EDM. This proposed research offers engineering values for optimizing the machining parameters and improving the machining performances of micro EDM.

CONTENTS

Abstract: The aluminum alloy AlMn1Cu has been broadly applied for functional parts production because of its good properties. But few researches about the machining mechanism and the surface roughness were reported. The high-speed milling experiments are carried out in order to improve the machining quality and reveal the machining mechanism. The typical topography features of machined surface are observed by scan electron microscope(SEM). The results show that the milled surface topography is mainly characterized by the plastic shearing deformation surface and material piling zone. The material flows plastically along the end cutting edge of the flat-end milling tool and meanwhile is extruded by the end cutting edge, resulting in that materials partly adhere to the machined surface and form the material piling zone. As the depth of cut and the feed per tooth increase, the plastic flow of materials is strengthened and the machined surface becomes rougher. However, as the cutting speed increases, the plastic flow of materials is weakened and the milled surface becomes smoother. The cutting parameters (e.g. cutting speed, feed per tooth and depth of cut) influencing the surface roughness are analyzed. It can be concluded that the roughness of the machined surface formed by the end cutting edge is less than that by the cylindrical cutting edge when a cylindrical flat-end mill tool is used for milling. The proposed research provides the typical topography features of machined surface of the anti-rust aluminum alloy AlMn1Cu in high speed milling.
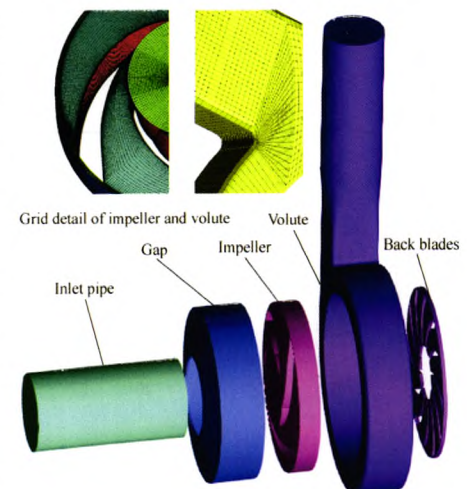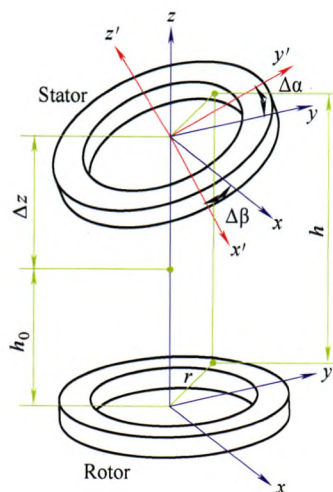
Complex Equipment and Sealing

Abstract: As the critical component, the impellers of the slurry pumps usually have blades of a large thickness. The increasing excretion coefficient of the blades affects the flow in the impeller resulting in a relatively higher hydraulic loss, which is rarely reported. In order to investigate the influence of blade thickness on the transient flow characteristics of a centrifugal slurry pump with a semi-open impeller, transient numerical simulations were carried out on six impellers, of which the meridional blade thickness from the leading edge to trailing edge varied from 5–10 mm, 5–15 mm, 5–20 mm, 10–10 mm, 10–15 mm, and 10–20 mm, respectively. Then, two of the six impellers, namely cases 4 and 6, were manufactured and experimentally tested for hydraulic performance to verify the simulation results. Results of these tests agreed reasonably well with those of the numerical simulation. The results demonstrate that when blade thickness increases, pressure fluctuations at the outlet of the impeller become severe. Moreover, the standard deviation of the relative velocity in the middle portion of the suction sides of the blades decreases and that at the outlet of the impeller increases. Thus, the amplitude of the impeller head pulsation for each case increases. Meanwhile, the distribution of the time-averaged relative flow angle becomes less uniform and decreases at the outlet of the impeller. Hence, as the impeller blade thickness increases, the pump head drops rapidly and the maximum efficiency point is offset to a lower flow rate condition. As the thickness of blade trailing edge increases by 10 mm, the head of the pump drops by approximately 5 m, which is approximately 10 % of the original pump head. Futhermore, it is for the first time that the time-averaged relative flow angle is being considered for the analysis of transient flow in centrifugal pump. The presented work could be a useful guideline in engineering practice when designing a centrifugal slurry pump with thick impeller blades.

Grid detail of impeller and volute   Volute

Gap   Impeller   Back blades

Inlet pipe

Abstract: As turbocharging diesel engines for vehicle application are applied in plateau area, the environmental adaptability of engines has drawn more attention. For the environmental adaptability problem of turbocharging diesel engines for vehicle application, the present studies almost focus on the optimization of performance match between turbocharger and engine, and the reliability problem of turbocharger is almost ignored. The reliability problem of compressor impeller of turbocharger for vehicle application when diesel engines operate in plateau area is studied. Firstly, the rule that the rotational speed of turbocharger changes with the altitude height is presented, and the potential failure modes of compressor impeller are analyzed. Then, the failure behavior models of compressor impeller are built, and the reliability models of compressor impeller operating in plateau area are developed. Finally, the rule that the reliability of compressor impeller changes with the altitude height is studied, the measurements for improving the reliability of the compressor impellers of turbocharger operating in plateau area are given. The results indicate that when the operating speed of diesel engine is certain, the rotational speed of turbocharger increases with the increase of altitude height, and the failure risk of compressor impeller with the failure modes of hub fatigue and blade resonance increases. The reliability of compressor impeller decreases with the increase of altitude height, and it also decreases as the increase of number of the mission profile cycle of engine. The method proposed can not only be used to evaluating the reliability of compressor impeller when diesel engines operate in plateau area but also be applied to direct the structural optimization of compressor impeller.

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Abstract: The dry gas seal(DGS) has been widely used in high parameters centrifugal compressor, but the intense vibrations of shafting, especially in high-speed condition, usually result in DGS's failure. So the DGS's ability of resisting outside interference has become a determining factor of the further development of centrifugal compressor. However, the systematic researches of which about gas film disturbance characteristics of high parameters DGS are very little. In order to study gas film disturbance characteristics of high-speed and high-pressure spiral groove dry gas seal(S-DGS) with a flexibly mounted stator, rotor axial runout and misalignment are taken into consideration, and the finite difference method and analytical method are used to analyze the influence of gas film thickness disturbance on sealing performance parameters, what's more, the effects of many key factors on gas film thickness disturbance are systematically investigated. The results show that, when sealed pressure is 10.1MPa and seal face average linear velocity is 107.3 m/s, gas film thickness disturbance has a significant effect on leakage rate, but has relatively litter effect on open force; Excessively large excitation amplitude or excessively high excitation frequency can lead to severe gas film thickness disturbance; And it is beneficial to assure a smaller gas film thickness disturbance when the stator material density is between 3.1 g/cm³ to 8.4 g/cm³; Ensuring sealing performance while minimizing support axial stiffness and support axial damping can help to improve dynamic tracking property of dry gas seal. The proposed research provides the instruction to optimize dynamic tracking property of the DGS.

Engineering Thermophysics
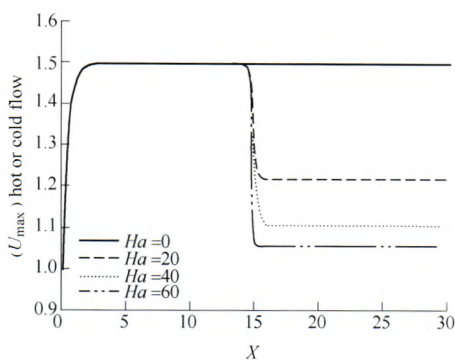
Abstract: This paper provides a numerical study of forced convection between hot and cold nanofluid laminar flows that are separated by a thin membrane, in a horizontal channel. Outer surface of channels' walls are thermally insulated and divide into two parts; namely NMP and MP. NMP is the channel's wall from the entrance section to the middle section of channel that is not influenced by magnetic field. MP is the channel's wall from the middle section to the exit section of channel which is influenced by a uniform-strength transverse magnetic field. The governing equations for both hot and cold flows are solved together using the SIMPLE algorithm. The effects of pertinent parameters, such as Reynolds number ($10 \leqslant Re \leqslant 500$), Hartman number ($0 \leqslant Ha \leqslant 60$) and the solid volume fraction of copper nano-particles ($0 \leqslant \phi \leqslant 0.05$), are studied. The results are reported in terms of streamlines, isotherms, velocity and temperature profiles and local and average Nusselt number. The results of the numerical simulation indicate that the increase in Reynolds number and the solid volume fraction lead to increase in Nusselt number. Meanwhile, the results also show that the rate of heat transfer between the flows increases as the Hartmann number increases, especially at higher values of the Reynolds number.
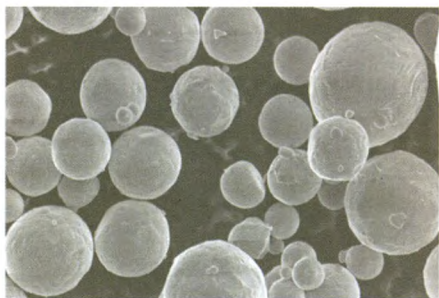
Abstract: Aluminum particles 15–25 μm in size are widely used in fuel propellants and underwater propulsion systems in national defense research. However, these particles are covered with an aluminum oxide film, which has a high melting point, so ignition is difficult. To improve the ignitability of high-energy aluminum powder and to understand the reaction phenomenon as a function of particle size(15–25 μm, 74–105 μm, and 2.38 mm) and oxidizer(air, CO_2, and argon), the natural oxide films are chemically removed. The particles are then coated with nickel using an electro-less method. The degree of nickel deposition is confirmed qualitatively and quantitatively through surface analysis using scanning electron microscopy/energy dispersive spectroscopy. To characterize the nickel coatings, elemental analysis is also conducted by using X-ray diffraction. Thermogravimetric analysis/differential scanning calorimetry (TGA/DSC) enable comparisons between the uncoated and coated aluminum, and the reaction process are investigated through fine structural analysis of the particle surfaces and cross sections. There are little difference in reactivity as a function of oxidant type. However, a strong exothermic reaction in the smaller nickel-coated aluminum particles near the melting point of aluminum accelerates the reaction of the smaller particles. Explanation of the reactivity of the nickel-coated aluminum depending on the particle sizes is attempted.

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