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Design of a New Type Aerostatic Rotary Bearing

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Abstract: Hydrostatic bearing is widely used in the field of precision mechanical machining and measuring, for its little abrasion and high rotary accuracy. So its performance directly influences the accuracy of fabrication and measurement. Restrictors are generally needed to regulate the fluid flow and pressure so that the hydrostatic bearing can bear external load. Conventional compensation involves fixed compensation and variable compensation, both of which need special devices or features to compensate the shaft's motion.

Self-compensating bearing regulates the flow with its own features, which doesn't call for additional restrictors. It may achieve high stiffness and precision using novel design. Since 1940s, when Hoffer proposed an automatic fluid pressure balancing bearing, design and research on self-compensating bearings was started. Slocum developed Hoffer's ideas, and he designed a self-compensating hydrostatic linear motion bearing, using fluid lines to connect the annulus supply hole and the pocket on the opposite side of the slider. Hereafter this idea was applied to journal bearings, and a high speed hydrostatic spindle was obtained, which allows for very high speed rotation with a minimum of heat generation and mid maximum load capacity. Kane and Slocum improved the structure, adding an elastically supported member to the bearing, which is deformed with the pressure change in the pocket. So the compensation effect is reinforced. Wasson and Slocum developed a self-compensating bearing whose compensating features are connected to the pockets via channels on the surface of the bearing, so compensation effect is gap-independent. Recently Kane et al proposed a hydrostatic bearing with angled surface self-compensation. The design consists of several round parts which can be easily manufactured and assembled, and achieves high stiffness and accuracy.

In this paper a new type aerostatic bearing is proposed based on Kane's design. Based on the bearing with angled surface self-compensation designed by Kane ea al., orifice restrictor is introduced to improve the axial performance, which is useful when the bearing is applied on a rotary table mounted on a machine tool such as a turning or milling machine. Combination of the orifice compensation and angled surface self compensation makes the bearing more effective to compensate the motion both in radial and axial directions. As the rotor displaces related to the stator, the flow rate through the orifice changes as well as that through the restrictor gap, so that pressure difference is produced to push the rotor back to its initial place. Fluid flow through the bearing was detailed described, and its equivalent flow restrictor network was built. And then the performance of the bearing was simulated by the mathematic model. The results shows that orifice improves the axial performance of the bearing without reducing the radial performance. Then rational bearing gap was discussed. It is concluded from simulations that small gap is favorable to load carrying capacity and stiffness and is able to reduce gas consumption. Bearing gap and restricting gap should be rational matched to achieve good performance. The length of restrictor land is required to be short as long as enough gas supply is available. A bearing designed in this paper with a 200 mm diameter can attain radial stiffness more than 150 N/μm and axial stiffness more than 200N/μm.

Keywords: Aerostatic bearing, Orifice, Self-compensation

Surface Generation and Chip Formation When Ultraprecision Turning of SiCp/Al Composites

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Abstract: Chip formation and surface generation were investigated when ultra-precision turning of SiC_p/2009Al and SiC_p/ZL101A composites using Single Crystal Diamond (SCD) and Polycrystalline Diamond (PCD) tools. The results showed that the machined surfaces took on many defects of pits, voids, microcracks, grooves, protuberance, matrix tearing etc. when examined by Scanning Electron Microscope (SEM). It was noticed that most of these defects had an intimate relationship with the removal process of SiC particle. The surface finish was much better when the SiC particles were removed by cut through or in-situ pressed into mechanisms. On the contrary, the surface finish was much inferior when the SiC particles were removed by crushed or pulled out mechanisms. Material swelling and side flow, tool-workpiece relative vibration, feed rate and tool nose radius, removal mode of SiC particles were these main mechanisms of surface generation. Generally, a saw-toothed chip was formed when ultra-precision turning this kind of material and the mechanisms of this type of chip were dynamic microcrack behavior, periodic variation of shear angle, strain concentration which induced by the non-uniform deformation of the workpiece material.

Keywords: Particle reinforced aluminium matrix composites, Diamond turning, Ultra-precision, Surface generation, Chip formation

Features investigation of acoustic emission signals under a simulative environment of grinding burn

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Abstract: Grinding burn is a common phenomenon of thermal damage that has been one of the main constraints in grinding in respect of high efficiency and quality. An acoustic emission (AE) technique was tried in an attempt to identify grinding burn on-line. However, the AE features of grinding burn are relatively weak and easily obscured by other AE sources. This paper presents an investigation of the AE features of the thermal expansion of several difficult-to-cutting materials, including in Nickel-based alloys and Ceramics, induced by laser irradiation, which was designed to simulate grinding thermal behavior. By using Short Time Fourier Transforms （STFT）, AE features，including in frequencies of AE signals, at the grinding burn temperature can successfully be extracted without other mechanical interferential factors. The followings are the investigation objectives of this paper: （1） To monitor grinding of nickel-based alloys，including in Inconel 718, MARM002(EQ), CMSX4 and Al_2O_3 ceramics by a thermocouple and an AE sensor. A set of laser heating experiments was arranged to simulate grinding thermal behavior. All experiments were carried out in the Lumonics JK704 Nd:YAG laser machine. Data logging software based on Labview has been developed. A thermocouple and an amplifier have been designed to build up and monitoring a system. In pencil break calibration the acoustic emission (AE) signals are analyzed.（2）To obtain the critical temperature of grinding burn. （3）To raise temperature by a pulse laser and obtain pure thermal AE signals. The tested results are good agreement with calculated results. From the tests, it was noticed that the temperature elevation curves were different for different materials and offset. The influential factors may be the laser spot size, thermocouple position and laser penetration.（4）To extract the AE signal frequency features by STFT. It is found for example, even though there are differences between AE signals under different off-focal length distances, the grinding burn frequences of Inconel 718 are same, （5）To compare frequency features between real grinding signals and the simulated signals. (6) CMSX4 burn metallurgical research. **Conclusions are as follows:** The bigger the temperature change of workpiece, the stronger the AE signals. The frequency features of AE signals of grinding burn are shown here for the different materials: (1) Inconel718: 200~450kHz,550~700kHz; (2) MARM002(EQ): 200~450kHz; (3) CMSX4: 250~550kHz; (4) Ceramic(Al_2O_3): 250~350 kHz. After the frequency features of AE signals of grinding burn are found , it will be easy to find grinding burn in a large AE signals of grinding machining. Such thermal AE features provide a firm foundation for analyzing and monitoring the AE features of grinding burn. The tests need for validating these findings for pattern recognitions. Other thermal AE features of grinding burn of different difficult-to-cutting materials are going to finding in the near future by us. A grinding burn on-line monitoring system will be build.

Keywords: Grinding burn; Acoustic emission; simulation; laser irradiation; features.

High Speed and High Precision ASJ Cutting Technology and Equipment

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Abstract: The abrasive suspension jet (ASJ) has great potential for cutting materials due to its high power and high precision. The full automatic ASJ cutting technology for singulating electronic chips has been commercially introduced into semiconductor industry. This paper explores the cutting capability of ASJ and introduces the ASJ cutting equipment for Micro SD card strips.

There are two kinds of abrasive jet, known as Abrasive suspension jet and Abrasive water jet. This paper explores the establishment of cutting capability equation of ASJ theoretically. Firstly, based on fluid mechanics, the abrasive power of ASJ is deducted; secondly, based on Rittinger's theory, the debris surface area generation is directly proportional to the abrasive power of ASJ, the cutting capability equation of ASJ has been developed:

:

$$hu = K\frac{S}{D}\frac{\pi}{4}D^2P^{1.5}\sqrt{\frac{2}{\rho_w}}\sqrt{\frac{1+r\rho_w/\rho_a}{1+r}}\frac{r}{1+r}$$

Moreover, the cutting capability equation of AWJ has also been developed:

$$hu = K\frac{S}{D}\frac{\pi}{4}d^2P^{1.5}\sqrt{\frac{2}{\rho_w}}\frac{r}{(1+r)^2}$$

The abrasive nozzle is same as the water nozzle in ASJ. Normally, the abrasive nozzle diameter is 3 times greater than the water nozzle diameter in AWJ. So ASJ has 9 times higher abrasive power and cutting ability than AWJ under identical abrasive ratio, pressure, abrasive nozzle diameter and abrasive size.

If d/D=1/3 in AWJ, and AWJ's abrasive ratio is 0.1~0.15 and ASJ's abrasive ratio is 0.3~0.5, So ASJ has 23 times higher best abrasive power and cutting ability than AWJ under identical pressure, abrasive nozzle diameter and abrasive size.

We choose ASJ for the singulation because ASJ is more powerful and more precise than AWJ. Based on complete cutting with 0.25mm ASJ, the JS800 ASJ Singulation has been developed for singulating Micro SD cards in semiconductor manufacturing. It consists of three units: ASJ engine, manipulator and handler.

The ASJ Engine is an abrasive cycle System, contains recharging abrasive subsystem, discharging abrasive subsystem, recycling abrasive subsystem and sieving abrasive subsystem. Recharging abrasive subsystem feeds useful abrasive into the high pressure abrasive vessel. Discharging abrasive subsystem generates high pressure ASJ to cut work piece. Recycling abrasive subsystem removes out useless particle and recycles the reusable abrasives. Sieving abrasive subsystem removes out oversized particle. The recycling abrasive subsystem can save 97% abrasive.

The manipulator contains XY table, vision fiducial alignment system and vacuum fixture. In order to reduce the load of X-Y table and well protect the X-Y table, moving an ASJ nozzle in the X-Y direction over a fixed strip fixture is being used for singulating strip. For accurately locating the jet relative to the cut paths, vision fiducial alignment system must be needed. To singulate the strip, each small part must be supported and held by a vacuum fixture. The fixture has been

designed such that its integrity is not affected by the closed path cuts made around the parts.

The full automatic ASJ singulation system has be equipped with a handling system such that the strips can be automatic loaded on the cutting fixture from strip magazine and the singulated parts can be automatic unloaded from the cutting fixture and loaded on JEDEC trays at the output side of the machine.

The ASJ cuts the Micro SD cards at speeds 300 mm/s and at acceleration 3000mm/ss. Its productivity is up to 3500UPH. Both process and machine performance was critical to meeting a process capability index (CPK) greater than 1.66. The ASJ process has been successfully implemented for cutting Micro SD cards.

Keywords: Abrasive suspension jet, High speed cutting, High precision cutting,

Aggressive Roughing Tool Path with Multiple Cutters for Pocket Machining using Medial Axis Transform

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Abstract

To CNC machine pockets, especially, with free-form boundary, roughing is crucial to their productivity, for this operation could simply take more than 60% of the total machining time. Right now, it is in high demand from industry that a new machining technique can efficiently cut pocket. Aggressive rough machining can be a solution, in which larger cutters are always employed and are fully immersed into the stock material. Although the aggressive roughing so far is the most efficient strategy, compared to the existing methods, no CNC programming technique is developed to support it, resulting in few applications in machine shops. To address this urgent demand in this work, based on the medial axis transforms of the pockets introduced in Part I, Part II proposes an optimal approach to multiple cutters selection and their tool paths generation for pockets aggressive roughing. First, tool paths of a specific cutter are quickly generated by using the pocket medial axis transform. Due to its unique characteristic, the tool paths ensure the maximum accessible space for larger cutters, at the same time, they are guaranteed gouging-and-interference free. Then, an optimization model of selecting multiple cutters is built to maximize the area of the machined region and bound the thickness of the remaining stock material under the tolerance. To demonstrate the advantages of this innovative approach, several examples are rendered and the results are compared with the existing methods. This approach can be directly implemented into the current CAD/CAM software to promote aggressive pocket roughing in industry.

Keywords: Pocket machining, Roughing tool path, Medial axis transform

In-situ Metrology System for Micro-Milling Machine

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Abstract:

In this paper, an in-situ metrology system was developed for micro-machined part inspection. The metrology system presented in this paper boasts several innovations that enable *non-contact*, *on-machine* measurement of a variety of geometric features encountered in micro-manufacturing applications with high accuracy and efficiency. The system combines high resolution distance measurement in the Z-axis from a confocal laser with the scanning position information from linear encoders in the machine motion platform to obtain 3-D coordinates of surface points. The measurement laser was implemented on the Microlution 310-S motion platform, it has the same working volume as the machine. Given the relatively small overall size of micro-machined parts and relatively high achievable scanning speed, it takes only a few minutes to scan an entire part with very high X/Y resolution. Furthermore, since the achievable resolution in X/Y is comparable to available surface profilers (e.g. Vecco interferometry optical profiler), measurement data obtained can be used for surface characterization. Therefore, this metrology system has the versatility to function as both CMM and surface profiler. If implemented in a 5-axis micro-milling machine, the metrology system can even applied for cloud-to-CAD comparison and reverse engineering by combining the scanning data from several different orientations.

A Keyence LT-9010M was chosen as the confocal laser sensor to use for this development. The operating principle is based on detecting reflected light intensity through a pinhole while using an oscillating objective lens to vary the focal plane of the emitted light. The reflected light intensity is the greatest when the focal plane occurs exactly on the surface of the measured object. The objective lens is oscillated using a tuning fork and the position of the lens is measured using a capacitance sensor; this measured position is directly related to the position of the focal plane. Thus, the distance to the surface of an object is calculated by recording the position of the objective lens that yields the most reflected light.

The confocal laser sensor was mounted to the Microlution 310-S using a patent-pending kinematic coupling system that enables the machine spindle to be interchanged with other devices. Measurements synchronized with the actual machine stage positions are enabled by connecting the +/-10V analog measurement output from the LT-9010M to an A/D converter on the machine controller.

The data collection for the metrology system was implemented as an integral portion of the CNC control platform. The machine controller is open architecture Delta Tau Turbo PMAC2. The program consists of two parts. The first part is a background thread implemented on the machine controller that synchronize and report the machine position and laser measurement data to the rotary buffer in the Dual-Port RAM, which can be accessed by the host computer. In the meanwhile, the host computer handshakes and downloads the data in a timely fashion from the rotary buffer and save it as a data file on the hard drive. The second part of the program is a motion program which drives the machine axes to scans the part with the desired resolution. The data collection module samples the synchronized machine position and laser measurement data at a specified sample frequency to capture a cloud of data. The X/Y sample resolution of the data can be varied by varying the motion program parameters and the sample frequency. The saved data file is then used by the post-processing software to conduct feature measurements.

In order to provide complete and robust metrology capabilities, a post-processing software package has been developed using MATLAB to manipulate and analyze the 3-D point cloud data collected for the measurement of the size, distance, geometric accuracy and surface roughness of various features encountered in micro-machining applications. In addition to the standard data analysis algorithms commonly used in CMM (e.g. least square regression for line, circle estimations) and surface profiler (algorithms for computing 2-D and 3-D surface roughness), the metrology system implements several unique features, which makes the system more flexible and easy to use, including:

- An automatic edge detector;
- An interactive selection tool;
- On-screen interactive dimension measurement;
- Interactive surface analysis tool.

The system is capable of non-contact, on-machine measurement of a variety of geometric features encountered in micro-manufacturing applications with high accuracy and efficiency. It can inspect the feature dimensions (like a CMM) and characterize the surface topography (like a surface profiler) within one operation. A micro-machined diamond-square-circle part was successfully inspected in-situ with the metrology system.

Keywords: In-situ metrology, micro-milling

Nonlinear robust control of a single DOF Magnetic Levitation System with electromagnetic parameter uncertainty

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Abstract

The magnetic levitation system's control problem is of considerable scientific interest because the system is open-loop unstable and highly nonlinear, and system's parameters are uncertain. It is very important to develop an effective controller that is robust to system parameter perturbation. In general, the electromechanical dynamics of a magnetic levitation apparatus is represented by a nonlinear model consisting of the state variables of position, velocity, mass, coil current, and input voltage. In this paper, we formulate the system by a third-order nonlinear differential equation. Based on this third-order nonlinear system, we first linearize the system by applying the feedback linearization method. Then, the controller is designed based on a global sliding mode technique, which is able to stabilize a linearized system. Experimental results show that compared to the classical PID controller, the proposed controller provides excellent transient response performance and the system is robust against the nonlinear parameter perturbation. Further experiments are carried out to test the robustness of the proposed algorithm. The results show that the GSMC is a robust controller, it can tolerant large uncertainty of the system parameter. From the experiments, sampling period is found to be an important parameter to affect the robustness of the GSMC controlled system. The reason is that: if a large uncertainty is set in the sliding mode control algorithm, then before the system is on the sliding mode surface, the output of the controller is quite large, sometimes larger than the maximum output ability of the amplifier in the real system. The system will not converge to the sliding surface, but chattering above or below it, but a small sampling period means if the system is closer to the sliding surface, it will be detected by the system, and thus the controller will compute a small output to push the system closer to the sliding surface. This process will gradually push the system on the sliding surface until it is stable, and the output of the controller will gradually reduce in the range of the amplifier output limitation. The analysis shows that in the practical GSMC controlled system there are two methods to improve the robustness of the system: either increase the actuator output ability or decrease the sampling period. With the limitation of the actuator output ability, the smaller the sampling period is, the more robust the controller will be. The further study of the SMC algorithm is to consider the integration of sliding mode control and intelligent control such as neural networks to overcome the chattering, disturbances and unmodeled dynamics in the SMC.

Keywords: magnetic levitation system, robust control, nonlinear system, sliding mode control, feedback linearization, sampling period

A FINITE ELEMENT BASED SEMI-EMPIRICAL MACHINING MODEL FOR ELECTROCHEMICAL DISCHARGE MACHINING (ECDM) IN GLASS

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Abstract: ECDM is a promising technology for high-performance micromachining of glass. Although experimental study on ECDM is growing steadily, its process modeling seems to be far lagged behind. Only a few ECDM models have been reported, and the existing ECDM drilling models neglected key factors such as material removal by chemical dissolution or machining degradation due to regime effect. In this paper, we develop a finite element based semi-empirical ECDM drilling model to overcome these defects. We predict the volume of material removal by one electrochemical spark as well as by multiple sparks. Heat transfer subjected to a single spark is simulated using finite element method, and we highlight the characterization of the heat source. We compare the predicted results with experimental results to validate the model. The results predicted by the model shows good agreement with experimental results. To display the effectiveness of this model, we use it to study the effect of the applied voltage and electrolyte concentration in ECDM.

Keywords: Electrochemical Discharge Machining (ECDM), Micro-hole Drilling, Process Modeling, Finite Element Method (FEM)

Improving the localization of the micro-dimples on the aluminum-alloy surface by through mask electrochemical machining with auxiliary anode

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Abstract

It has been recently presented that the micro-dimples can be generated by the modified through mask electrochemical micromachining (TMEMM). In this paper, the auxiliary anode was consisted in the mask of the modified TMEMM to improve the localization of the micro-dimples. Numerical simulation of the current density in the interelectrode gap was verified the proposed method theoretically and the effect of the auxiliary anode on the machining localization on the aluminum-alloy surface was investigated experimentally. The experimental results indicated that the machining localization was significantly improved by the auxiliary anode successfully and the etch factor was decreased with the increasing machining voltage.

Keywords: TMEMM, auxiliary anode, aluminum-alloy, micro-dimples, localization

Comparing Study of Joining YBCO Bulks with Different Solders

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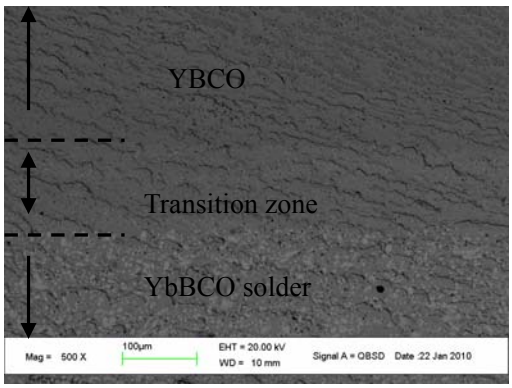
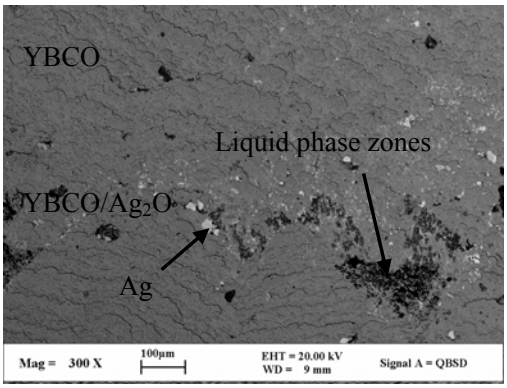
Abstract: In this paper, three kinds of superconducting YBCO solders have been fabricated by chemosynthesis method to join HTS (High Temperature Superconducting) YBCO (Y-Ba-Cu-O) bulks. The joining processes with these solders were performed in air. The microstructures of the joints were evaluated by SEM and EDS. Furthermore, the superconducting properties of the joints were estimated on the basis of magnetic levitation force. The results show that three kinds of soldered joints without cracks were obtained. And the joint using YbBCO solder formed multi-layer structure due to the interdiffusion of the elements. And some liquid phase zones were discovered in the joints at soldering temperature with Ag or Ag_2O doped YBCO. All of three kinds of soldered joints are superconductive. And the joint with [0.75Y123+0.25Y211] +10wt% Ag exhibits the best superconducting property and the highest magnetic levitation force of the joints reached 93.5% of the original bulk magnetic levitation force.

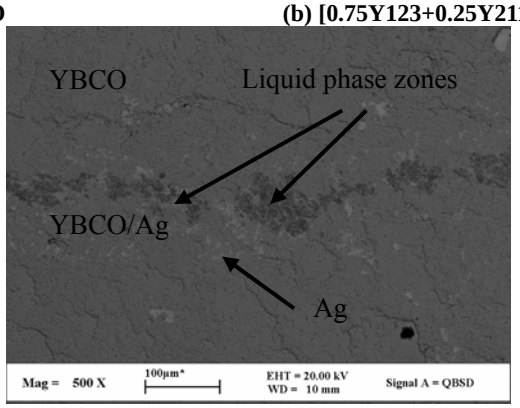
Keywords: YBCO, Solder, Magnetic levitation force



(a)YbBCO



(b) [0.75Y123+0.25Y211] +10wt% Ag_2O



(c) [0.75Y123+0.25Y211] +10wt% Ag

The microstructures of the joints with three kinds of solder

Flow Behaviour Analysis and Experimental Investigation for Emitter Micro-channels

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Abstract: Emitter is a key component in drip irrigation system. The labyrinth-channel of the emitter is about 0.5~1.0mm and its structure is very complex so it is easy to be clogged by particles escaped from filtering system. In this paper, on the basis of analyzing the flow field of water-sand two-phase flow in micro-channels of drip irrigation emitters, the anti-clogging mechanism of micro channels was discussed. This paper investigates the practical flow of water, mixed with sand escaped from filtering, in the labyrinth channel, and conducts some research work on the clogging mechanism of the labyrinth channel's structure. CFD (Computational Fluid Dynamics) analysis has been performed on liquid-solid two-phase flow in labyrinth-channel emitters. Based on flow visualization technology—Micro-PIV (Particle Image Velocimetry), the flow in labyrinth channel has been photographed and recorded. The path line graph and velocity vector graph are obtained through the post-treatment of experimental results. It was concluded that turbulence-flow model was more rational than laminar-flow model, and there were several vortices and low-velocity regions in the labyrinth channel and hence causing clogging. The graphs agree well with CFD analysis results, so CFD analysis can be used in optimal design of labyrinth-channel emitters. According to ISO standard of emitter clogging test, orthogonal experiments were designed and carried out for rectangular and zigzag channels with different structure parameter. The optimum structural parameter range of the rectangular and zigzag channels was obtained. The relationship of the sand diameter when clogging occurred with channel width was put forward and some suggestions about the choice of the filtering system were obtained. Finally the anti-clogging optimal design and analysis were conducted for rectangular and zigzag channels, and their anti-clogging performance was obviously improved.

Keywords: Drip irrigation emitter; Labyrinth channel; Two-phase flow analysis; Anti-clogging; Micro-PIV

Finite Element Simulation of Textile Composite Stamping On Double Dome

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Abstract: Textile composite possess good stability and formability which result from the stretching of fibers in fiber direction and large amount of extension in diagonal direction. These characteristics enable textile composites to drape into fairly complex shape. Stamping is one of the most effective ways to form textile composites.

In forming simulation of textile composites, geometrical approaches are fairly simple and computationally effective but it has drawback as they do not consider the mechanical behaviour of fabric reinforcement and processing parameters. The alternatives to these geometrical approaches are generally based on finite element method, which are able to take into account the mechanical behaviour of fiber constitutive phases and complex boundary conditions involved in stamping set-up.

In this paper, an approach for forming simulation of textile composites is presented. A previously developed continuum mechanics based non-orthogonal constitutive model is used to represent the anisotropic nonlinear material behaviour of textile composite fabrics under large deformation during stamping. The constitutive model is imposed on conventional shell elements to equivalently characterize the global mechanical behaviour of woven composite fabric during forming. The proposed forming simulation approach is demonstrated over a balanced plain weave composite fabric on a benchmark example of double dome stamping. A quarter of the model (235mm x 135mm) has been selected for data comparison since this model is symmetric in the *x*- and *y*-axes with origin at the centre of the model. To be consistent with experimental setup, a constant 100N binding force is applied on the binder during simulation, and the coefficient of friction between the composite fabric and the tooling is taken to be 0.2. The punch is assigned a total stroke of 60mm in an incremental way.

Simulation results such as material draw-in along fabric edge, boundary profile and shear angles between weft and warp fiber yarns along a selected path under a punch stroke of 60mm are compared to the respective experiment data. The results demonstrate that numerical profile is very close to experimental body outline appearance, although there is little disagreement in the warp direction. The maximum shear angle predicted from the numerical model is about 36.3° as compared to 39.5° measured from experiment with an error of 7.71% (8% stated in the reference paper).In an overall sense, the numerical simulation with the current non-orthogonal constitutive model predicts a quite similar deformed shape as from experiment forming, for the woven composite fabric under double dome device. The numerical simulation demonstrates the necessity and efficiency of the non-orthogonal constitutive model in capturing the anisotropic material behaviour that woven composite fabrics render in forming. The main advantage of this approach lies in its simplicity. It is easy to implement, and does not drastically increase the burden of computation.

Keywords: Textile composite, Forming simulation, Non-orthogonal constitutive model

The Significance of Deposition Point Standoff Variations in Laser Direct Metal Deposition

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Abstract: To investigate the influencing rule of the standoff distance variations between the nozzle outlet and the powder deposition point on forming dimensional accuracy, the thin-wall metal parts were fabricated using three different standoff distances by experiments. The experimental results show that the top surface unevenness of thin-wall parts can be compensated automatically on the consequent successive layers when the standoff distance is less than the powder focal length from the nozzle outlet to the powder focal point, and the poorer results are obtained when the standoff distance is equal to or more than the powder focal length in the deposition of stainless steel 316L under open-loop control. Based on the experimental results, the steady standoff distance can be acquired and the difference between the building height and the ideal height of thin-wall parts can be compensated automatically in several layers by theoretical calculation.

Keywords: Laser direct metal deposition, Standoff distance, Thin-wall part, Shape accuracy

Effect of Low-Power YAG Laser on Welding Characteristics of Pulsed MIG Welding of Magnesium Alloy

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Abstract: As a lightweight alloy, magnesium has not only low density, but also high strength, workability, good shockproof performance and corrosion resistance, etc. With the wide application of magnesium alloy structural parts, the connection problems have to be solved. Welding is undoubtedly one of the best connection methods. In recent years, welding of AZ31B magnesium alloy has been carried out at home and abroad using electron beam welding (EBW), friction welding, activating flux tungsten inert gas (A-TIG) welding, laser beam welding (LBW), hybrid laser-tungsten inert gas (LATIG) welding, hybrid laser-metal inert gas (LAMIG) welding, but there were few reports concerning magnesium alloy of metal inert gas (MIG) welding. Compared to other welding methods, MIG welding is not only capable of better gap bridging, but can also make up for the lost alloying agents during welding; at the same time, it can achieve high-speed welding of thick plates as well. But a series of problems specific to the welding process are caused due to the peculiar physical properties of magnesium: density is 1700kg m^{-3} and melting point is 650℃, and boiling point is 1090℃. In recent years, German named H. Wohlfahrt and M. Rethmeier, Japanese named T. Ueyama and K. Nakata and Dalian university of technology in China have made a systematic study on MIG welding of magnesium alloy. They found that many spatters with big size were observed easily using conventional pulsed MIG welding alone, and the scope of suitable parameters was very narrow. Due to the low density and the small surface tension coefficient of magnesium alloy, metal transfer is difficult to realize and droplets flutter unsteadily on the tip of wires. Overheated droplets easily explode because of the small range of temperature between melting point and boiling point of magnesium (<500℃), thereby causing welding spatter. It means that the time of metal transfer period needs precisely controlling: droplets must meet necessary conditions for transition within a reasonable period of time to avoid explosion for overheating. However, the current waveform of conventional pulsed MIG welding is simple and the parameter ranges are difficult to hold and therefore the time of metal transfer period can't be controlled accurately, which may lead to welding spatter and decline of welding quality. In this paper, the method of low-power YAG laser assisting pulsed MIG welding of magnesium alloy is adopted, and arc shape and mode of metal transfer are monitored through high-speed camera. The problems of conventional pulsed MIG welding of AZ31B magnesium alloy and the effect of low-power YAG laser on the welding characteristics above are analyzed and researched. The experiment results show that mode of metal transfer of pulsed MIG welding of magnesium alloy contains two modes: globular transfer under lower pulsed current and spray transfer under higher pulsed current. With globular transfer mode, the diameter of spatter granule is about 2 to 3 times bigger of wire diameter, and a large number of spatters can be seen. Compared to globular transfer, droplet size of spray transfer is minor and the diameter is approximate to filler wire, but the discontinuous segment of forming shows that metal transfer is still not stable. For spray transfer, pulsed current is the key factor to promote metal transfer. Spray transfer modes contain project transfer and sub-project transfer. The former is about 2 times as long as arc period and the latter takes nearly 3 times longer than arc period. Typical welding spatter forms of pulsed MIG welding of magnesium alloy include globular repelled transfer and explosive transfer. This form of globular repelled transfer appears frequently, and spatters will be produced if the droplets fall outside the molten pool. However, explosive transfer will cause a wider range of welding spatter and relatively large losses. This phenomenon usually occurs after three arc periods in the form of spray transfer. With globular transfer mode, laser easily acts on droplets because of their large size, which will lead to the explosion of droplets for local overheating. When spray transfer mode is adopted, mode of metal transfer after introducing laser turns into stable project transfer mode. Laser forms keyhole on the surface of parent metal where magnesium alloy evaporate violently. Conducting channel has priority to build at the keyhole where great amounts of metal vapor exist because the ionization potential of metal vapor is lower

than that of gas atmosphere. As a result, the arc root is compressed and thereby the arc effective section shrinks. The results show that laser changes the frequency and mode of metal transfer by influencing the area of arc effective section, which improves welding stability and reduces spatter loss. The weld appearances of hybrid laser-pulsed MIG welding of magnesium alloy are homogeneous and continuous with dense and regular weld ripple, and welding spatter decreases significantly. Compared to pulsed MIG welding, the frequency of metal transfer of hybrid low-power YAG laser-pulsed MIG welding of magnesium alloy increases 43% at most, and the spatter loss coefficient decreases from 21% to 10%.

Keywords: Magnesium alloy, Hybrid laser-pulsed MIG welding, Metal transfer

A Significant Advantage and Innovation in Warm/hot Sheet Hydroforming

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Abstract:

The review of hot hydraulic bulging test, the simulation of cylinder cups of Al5A06-O and Titanium alloy TC4 on the platform MSC. Marc and experimental verification of Al5A06-O cylinder cup were presented in this paper. The review shows that flow stress determined by hot bulging test is more suitable to reflect the material properties in the processing of warm/hot sheet hydroforming. The simulation of cylinder cup deep drawing with heated media, warm/hot hydro-mechanical sheet deep drawing for cups and microstructure investigation make the conclusion that non-isothermal forming mode can get the larger LDR of cup compared with isothermal temperature forming mode. The significant advantage for warm/hot sheet hydroforming that can get the maximum drawing height of cups compared with conventional sheet hydroforming is obvious.

Keywords: sheet bulging test, FEM, experiment verification, cylinder cup, LDR

Dynamic Modelling and Analysis of Individual Pitch System of LSHAWT

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Abstract: One of the most universal methods of the pitch drive system is that every blade has its own individual pitch drive system in an MW scale wind turbine, nowadays. It offers the possibility to replace the large-scale and expensive braking system, and to control the blade using individual pitch control strategy. When designing the pith control strategy, the dynamic behavior of the individual pitch system is a key factor. However, in existent researching files, the research on pitch adjustment is mainly centered on control rule and design, or centered on mechanical features or electrical characteristics. In general, the previous research is unilateral. The electromechanical coupling model and running mechanism of the whole individual pitch system has not been reported in existent literatures. In order to deeply analyze and optimize the individual pitch system of large scale horizontal axis wind turbines (LSHAWT), a typical individual pitch system is taken as the objective, in which the induction motor, three-stage planetary gearbox and motor vector control technology were adopted. When the pitch controller sends out the pitch command, through the motor shaft, planetary gearbox and drive pinion, the torque produced by the drive motor is delivered to the inner toothing and drives the blade to rotate around the pitch axis. Meanwhile, the position sensor feeds back the information of pitch angle to the pitch controller. According to the control requirement of wind turbine, the pitch position demand from the pitch controller is compared with the measured pitch position. The error through a PI controller generates speed command of the drive motor. Then, the speed command is compared with the measured rotor speed, and the error through the PI controller generates torque command. Based on the analysis, its nonlinear dynamical model was established, mainly including three parts: induction motor model in *d*-*q* frame, dynamic model of three-stage planetary gears and transmission shaft model. Then, the dynamic responses of motor-gearbox-blade system were analyzed. When modelling, the drive motor vibration, the magnetic saturation, space harmonic and tooth harmonic are not considered, the winding of per phase is considered to be symmetrical, in synchronously rotating *d*-*q* frame. The axial displacement of the driveline is neglected; some influence factors, such as static transmission error, gear modification coefficient, gear backlash, elastic deformation of drive shaft, are considered; the bearing is regarded as rigid body. In order to reflect the actual running situation of the pitch system as much as possible, the relative parameters in model mainly come from an actual wind turbine. Since the rated speed of the drive motor in the pitch drive system is 3000rpm, three-phase 380V/100Hz power supply is then applied to the motor to investigate the dynamic response of the motor−gearbox−blade system. On these bases, the control model of the pitch drive system for an MW scale wind turbine is constructed in MATLAB, in which the mechanism, electric and control models are integrated; the rotor flux field-oriented vector control and double close-loop servo control with speed and position feedback were employed. In simulation, the algorithm TR-BDF2 was adopted to solve the dynamic equations. The research results show that the deviation between the pitch angle and its command value is very small in steady state; due to impact effect produced by gear backlash, both angular speed and angular acceleration fluctuate in some regime; since the pitch load is time-varying, the asynchronous pitch angles between different blades appear, while blade rotating near to the

command position. In this work, a reasonable explanation for running mechanism is given, which is helpful for optimization design and control for the individual pitch system. Meanwhile, a practical way of modeling the individual pitch system in large scale wind turbines is proposed.

Keywords: wind turbine; variable pitch system; servo drive; electromechanical coupling

Research on Electro-hydraulic Proportional Load Sense Separate Meter In and Separate Meter Out Control System

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Abstract: In this paper, Separate Metering or Independent Metering technique is introduced to achieve good dynamic characteristic as well as energy saving performance in hydraulic system especially for mobile machinery. The conception of Separate Metering technology is proposed since the 1990s, by increasing the control degree of freedoms in Separate Metering hydraulic system, both the flow rate of the actuator and the pressure in the actuator chamber can be controlled simultaneously for improving system performance, however the increasing control degree of freedom make the controllers designed for Separate Metering system be more sophisticated and difficult to develop than the traditional valve controlled systems. There were several controllers designed for Separate Metering system, but the performance comparisons of different controllers are rarely available; systematical analysis of design principle for the choice of valve parameters for Separate Metering valve which is to apply in hydraulic system have not previously studied yet; most of the systems studied by researchers are one-cylinder control systems, and the two-cylinder Separate Metering control systems are rarely studied; how to combine Separate Metering control technology with a fixed displacement pump system or an variable displacement pump control system are also discussed; additional function of Separate Metering valve which are used to replace the traditional multi-directional valve control are also studied, the above mentioned problems consist of the main research points of this paper. Different control strategies included the classical PID feedback and feed forward controller, Calculation Force controller as well as Adaptive Robust Controller designed for Separate Metering system are proposed and tested both by simulations and experiments; it is found that the designed nonlinear Adaptive Robust Controller achieves the best control accuracy among all of the designed controllers, the trajectory tracking error of PIDFF,CFC as well as ARC are within 0.015m, 0.002m,0.0005m respectively; but we have to keep it in mind that we should choose the suitable controller according to our design objectives, not merely to pursue the control accuracy at the expensive of the high cost of the nonlinear controller. The influence of the design parameters of Separate Metering valve such as dynamic frequency, dead-band, damping ratio on the controllability of Separate Metering system are evaluated by simulation , The simulation model is experimentally verified by the comparison of the experimental measured and theoretical simulated results with the same input signal in the open loop control form, the modification to the simulation model have been made according to the discrepancies of the dynamic response of the velocity of the piston and the pump outlet pressure to minimize the discrepancy to an acceptable level, then a number of simulations had been done to evaluate the influence of various design parameters of Separate Meter valve, it is found that the dynamic frequency of separate meter valve has great influence on the controllability of the close loop Separate Metering control system, if the frequency is lower than 5HZ, the system response is too slow to satisfy the high velocity control accuracy requirement of Separate Metering system, the damping ratio is also required to stay at an desirable range to achieve the good control velocity control performance, the direct dead-band compensation method is useless for improving the control characteristic of the Separate Metering system if the frequency of the Separate metering valve is lower than 5HZ, a feed-forward dead-band compensation control strategy is then proposed to improve the trajectory tracking performance of Separate Metering system, the obtained simulation results shows the effectiveness of the proposed strategy. Separate Metering technique is extended to a two-cylinder control system for improve velocity control dynamic characteristic as well as energy saving performance, when Separate Metering technology is proposed to be used for a synchronization motion control system, Separate Metering system has achieved faster velocity control dynamic response than the traditional proportional valve controlled system, in addition the good stability is maintained when the system run in the overrunning load condition, the synchronization error for the traditional valve control system is within 0.005m/s and the settle time is 0.15s when applied with overrunning load, the synchronization error for the separate meter system is within 0.002m/s and the settle time is 0.06s when applied with overrunning load. A two-cylinder system which possesses asymmetric characteristics due to the existence of a check valve in one cylinder and the absence of the check valve in the other cylinder is studied, the controllers for the two cylinders are designed respectively, the proposed gain regulation method are used to control the motion of the two cylinders, the experimental synchronization error is within 0.005m/s with the proposed controllers. The method how to combine Separate Metering technique with open center fix displacement pump control system is also studied, three Separate Metering valves are proposed to control the motion of the piston within the cylinder, the back chamber pressure of the cylinder as well as the pump outlet pressure, the pressure difference between the motion control Separate Metering valve is modulated according to the velocity command of the piston within the cylinder given by the operator is proposed to improve the energy saving performance of the whole system, the obtained experimental results shows the proposed method increases by 10 percent of energy saving performance within the defined load cycle for Separate metering hydraulic system compared with the traditional open center fixed pump control system. Combining Separate Metering technology with load sense technique is also studied, controllers are designed for

both the heavier load cylinder and the lighter load cylinder respectively , simulation shows the effectiveness of the proposed control strategies in achieving more energy saving performance, the 15 percent energy saving performance can be achieve compared with traditional load sense system within defined load cycle for hydraulic system. Anti-saturation function of Separate Metering control system is studied and realized in the designed controller experiment tests, the anti-saturation performance is better and faster than the traditional multi-directional valve control system. All obtained results attempt to provide some theoretical basis and reference applications of Separate Metering technique for the engineers in the field of hydraulic system.

Keywords: Separate/Independent Metering, speed control, load sensing, Energy saving

Calculation of the Chipping Thickness in the Process of Spiral Mining Head Breaking the Cobalt-rich Crust

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Abstract: Cobalt-rich crust,which grows in the smooth slope of seamount ranged from 800 to 3000m is one of the most attractive mineral resources In the deep sea bed.Its average thickness is only 4 to 6 centimeters,and is rich in strategic resources such as cobalt,platinum,nickel,manganese,copper,iron,phosPhorus,titanium,zinc,lead and cerium etc. Because of its practically strategic, economic and political significance，cobalt-rich crust has become a great concern in ocean resource exploitation for every country.

One of the starting point of the research of deep ocean mining system of cobalt-rich crust is to insure the reliability and long service life of the system ,and to get the largest mining cobalt-rich crusts with minimal power consumption. The environment at the deep sea bottom is very bad and very complex, when the mining machine working. The load of the spiral mining head has a direct relationship with the instantaneous chipping thickness of the cutting tooth. Whether the calculation of the instantaneous chipping thickness is correct or not，which directly affects the simulation results of the load on the spiral mining head.

In this paper, a chipping thickness model has been established in different working conditions, which is related to the characteristics of tiny topography and the axis height of mining head traction speed and rotation speed.explain the mechanism of peeling off and breaking up the cobalt crust and bedrock; The area of chipping have something to do with the rotation radius、rotation speed and feeding speed of the spiral mining hea. For different tinytopography and cutting depth, we build up different calculation model of the cobalt crust chipping depth.

In a word,the research outcome has a theoretical and practical significance to mining cobalt-rich crust in the future.

Keywords: Spiral Mining Head, Chipping Mechanism, Thickness calculation.

Experimental Research on 2D Digital Servo Valve

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Abstract: The construction and working principle of 2D digital servo valve which uses a stepping motor under closed-loop control as the electro mechanical converter are first introduced. Then an embedded controller of 2D digital servo valve is designed. In order to make sure the electro mechanical converter has a fast response speed and high position accuracy, the stepping motor is controlled as a synchronous servo motor, where a 90 phase shift and continuous variation of sinusoidal current is supplied to each phase of stator to ensure that the output angular displacement of rotor can quickly track the variation of the input signal. In order to acquire the practical performance, an experimental system is established, and then the experimental investigations of valve properties are carried out. Experimental results show that 2D digital servo valve, using the stepping motor as the electro mechanical converter, has both excellent static and dynamic characteristics. Either repetitive accuracy or resolution is less than 1%, while the bandwidth of the valve is about 130Hz at -3dB gain for 25% input signal.

Keywords: 2D digital servo valve, Dynamic response, Electro mechanical converter

Transient Response and Simulation of Hertz Contact/Impact of Flexible Bodies

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Abstract: The transient response to longitudinal impact of flexible rods with Hertz contact is closely related to the extent of deformations with different impact parameters. Johnson [8] pointed out that a smaller and lower impact velocity could cause deformation on the surface of metal. So in order to avoid the influence of collision-induced deformation, the collision speed limit did not exceed 0.3m/s in the vast majority of theoretical and experimental studies. The impact of a hammer on a drill rod is a typical longitudinal impact of 2 flexible rods. Based on one-dimensional elastic wave theory, Liu [9] et al made a study on the longitudinal impact of a hammer on a drill rod, in which Hertz contact effect so-called "end effect" was modelled by a linear spring. The experimental results were in agreement with analytical solution on condition that the impact velocity of a hammer on a drill rod was 10m/s. Zhu[10] et al performed experiments to investigate the impact of an aluminium rod with a hemispherical end on another with a flat end on condition of low impact velocity (0.21m/s.) The experiments results showed disagreements with the contact stress determined by Hertz theory. He stated that Hertz contact theory was not applicable to the impact of flexible rods. Therefore, the axial impact of flexible rods with Hertz contact so-called "end effect" remains to be further studied.

On the basis of the previous work published by Hunter [17], Zhang [18] points out that the Hertz nonlinear contact-impact is modelled by an equivalent linear spring. The nonlinearity of impact is linearized with an equivalent linear spring. The Hertz contact deformation is substituted by the spring deformation. By means of the equivalent linear spring above, the model, a finite long hammer with a spherical end axially colliding with a semi-infinite drill rod at some initial velocity, can be converted into a planar impact model of a hammer axially colliding with a drill rod through a spring indirectly. The analytical solution of longitudinal impact of a hammer on a drill rod is given using one-dimensional elastic wave theory. This paper numerically analyses and presents transient dynamic behaviours of a finite long hammer with a rounded end of different curvature radii axially colliding with a semi-infinite drill rod at an impact velocity of 10m/s by means of the explicit dynamic FEA software LS-DYNA. The comparison between the analytical solution and the numerical solution is made.

Simulations demonstrate that the historical impact curve of analytical and numerical solutions between hammer and rod agrees well when curvature radius is larger. The disparity between the analysis solution and the numerical solution becomes wider as the curvature radius of the hammer decreases. The smaller the curvature radius is, the wider the disparity is. When the impact velocity is very high and the contact radius of curvature is very small, the numerical solution is inconsistent with the analytical solution.

According to Hertz theory and Von Mises's shear strain-energy criterion, the stress reaches the critical value and plastic deformation all over yields in four different conditions. Yield deformation region in rod initiates from a point beneath the contact surface and grows around in an approximate spherical way as contact pressure increases. In the deep of rod, elastic region encases yield region in the whole process. When curvature radius R = 200mm, the contact surface elements will not yield. Yield region is encased by the contact zone and the surrounding elastic zone. As curvature radius decreases (R=100mm or 50mm), the elastic region on impact surface shrinks gradually and the yield region reaches the contact surface. A yield ring encircled by elastic region and contact boundary emerges. When R=11mm, because curvature radius is smaller, the contact pressure get much higher. As a result, the entire region beneath the contact surface becomes yield region. The boundary of yield region exceeds that of contact zone and unconstrained deformation region finally forms, which provides possible deformation space for yield region, significant plastic deformation will occur. The significant plastic deformation reduces the intensity of the contact pressure pulse. As a result, loading and unloading curves of contact shift down and the energy that is converted into elastic wave decreases. Therefore, numerical solution of dimensionless impact force is inconsistent with analytical solution on condition of short curvature radius. On condition of large curvature radius since the deformation of yield region is constrained by the surrounding elastic region, no significant plastic deformation appears. The numerical solution of impact force in elastic impact agrees well with the analytical solution solved with quasi-static method.

The validity of the theoretical analysis is affected by the extent of plastic deformation, which depends on the impact velocity, the contact radius of curvature and material properties. When yield region is encased by the contact zone and the surrounding elastic zone, no significant plastic deformation occurs on the surface of contact zone. The analytical solution of impact force with Hertz transient contact is in good agreement with numerical solution. The finite-plastic deformation has an inconspicuous influence on transient response of impact.

Keywords: Hertz contact, Flexible rod impact, Transient response

Experimental Investigation on Vibration Control for Rotor-bearing System with Active Magnetic Exciter

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Abstract: Reduction of rotor vibration is very important for the safety and the efficient functioning of turbomachinery in industry processing which demands fault-free operation. In reality, however, no rotor's operation is vibration-free due to various excitations which will cause malfunctions even disasters. Two dominant types of vibration in industrial turomachinery are synchronous and subsynchronous vibration. Synchronous (frequency at running speed) vibrations are normally excited by residual unbalance. The second, more serious types of vibration occur when non-conservative tangential forces (cross coupling) act to excite a lateral natural frequency that lies below the running speed, thus the name subsynchronous vibration.

As the dominant type of excitation force, unbalance is always an interesting area for rotating machine. In recent years, several vibration control facilities aiming at eliminating synchronous vibration as the machine working was presented, such as active balancing facilities, controllable squeeze oil-film damper, and Active Magnetic Exciter (AME) et.al. Result of these researches indicates that these methods have served well.

Based on fault mechanism and risk analysis, and by bionic design, a Fault Self-recovery(FSR) system, which is a dynamic system to store, supplement and transfer the self-recovery force, is endowed to a machine with the ability to maintain the machine in a healthy state. In this paper, for minimizing the vibration level as the machine working and realizing vibration fault-free of rotor-bearing, the FSR mechanism is introduced and investigated in detail. Self-recovery force, including compensation force, cleaning force, repairing force, adaptive regulation force, excitation response force, immunity force, self-protecting force and cooperation force etc, can be used to depress the oncoming destructive force which is not to come into being or to be eliminated during operation. In this paper, three control strategies are investigated to realize the vibration control as fast as possible.

1) Searching in whole circle

There are two parameters which are amplitude and phase should be determined in the process of vibration control. According to the periodical characteristics of triangle function, the process of current phase optimizing is conducted in whole circle. Take phase ϕ as the optimizing parameter, square of residual vibration amplitude A as optimizing target and the number of phase selection times as constraint conditions.

2) Fast Optimizing Control

At the beginning of the vibration control, a tentative self-recovery force is needed. If the phase is occasional, it may increase or decrease the vibration level depending on the relationship between the phase of controlling force and fault force. Thus, The Fast Optimizing Control(FOC) strategy can decrease the amplitude of vibration as fast as possible.

3) None Mistaking Control

In previous control strategy, there are always steps which will lead to vibration increase. We call these steps as "mistaking control". If the first tentative force phases in P region, then in whole controlling process, there isn't mistaking control step. For this purpose, numerical method of rotating machine dynamics is utilized to predict the phase of response at journal bearing lags in controlling force. Thereby, the needed controlling force phase can be determined.

Experimental study was conducted on a test rig at various rotating speed. One meter long rotor, which has a diameter of 50mm, is derived by a 20KW motor. The rotor was supported by two five pads tilting pad bearing. The span between two bearing pedestal is 490mm. There are sixteen evenly distributed screwed hole used to add unbalance on the disk. A keyway was milled

on coupling connected to motor. AME, which can provide multi-harmonic force, is taken as the actuator of vibration fault self-recovery system. Four Bently 3300 proximity probes are used to measure the vibration near bearing. Data acquisition and analysis instrument OROS38 is used to monitor and evaluate the vibration of rotor as well as the efficiency of controlling.

Aiming at the dominant types of vibration in industrial turomachinery，the paper introduces FSR mechanism to maintain the machine in a health state. As synchronous (frequency at running speed) vibrations are normally excited by residual unbalance. Numerical and experimental study was conducted to verify the effectiveness of these strategies. Results of the investigation indicate that the presented non-mistaking control strategy can minimize synchronous vibration no more than three second. It effectiveness is obvious.

Keywords: Vibration, Fault Self-recovery, Active Magnetic Exciter, Subsynchronous

Study on In-situ Preparation and Growth Mechanism of TiC_xN_{1-x} Whiskers

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Abstract: $Ti(C_xN_{1-x})$ whiskers were prepared using TiO_2 and carbon mixed powder as the starting powder at the atmosphere of nitrogen by the carbothermal reduction process. NaCl and $NiCl_2$ were added into the starting powder as the cosolvent and growth adds of impurities, respectively. An effect of the content of TiO_2 and carbon in the starting powder on the $Ti(C_xN_{1-x})$ whiskers was investigated. It is found from SEM and XRD observations that three types of $Ti(C_x N_{1-x})$ whiskers are obtained when the different mol ratios of C and Ti are applied. The growth of whiskers is not only urged by the droplet on the top of whiskers, but also initiated by the helical dislocations. The growth of TiC_xN_{1-x} whiskers is controlled by the gas-liquid-solid mechanism as well as gas-solid mechanism.

Keywords: $Ti(C_xN_{1-x})$ Whisker; In-situ Preparation; Growth; Mechanism

Active Magnetic Bearing Support Parameters Identification Based on Finite Element Model Updating Using FRF Data

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Abstract

Active Magnetic Bearing（AMB）is a high-tech product developed in recent years, which characterized by non-fiction、non-abrasion、non-pollution and energy saving. It has been in widespread use in Mechanical Engineering、Astronautics、Aeronautics, etc. Rotor-bearing structure in aviation multi-electric engine, for example, takes AMB as one of the preferred support. Magnetic bearing and journal bearing share many common support characteristics but also show some differences. For instance: There is cross coupling relationship between the bearing parameters (stiffness and damping) and the controller parameters of magnetic bearing; the bearing parameters cannot be known exactly after the variation of dynamic characteristic parameters (by adjusting the circuit parameters). It seems to be of particular importance to focus on the parameter identification of AMB with the application trend of high-speed and flexible rotor system. It is important to determine the values of the Active Magnetic Bearing (AMB) support stiffness and damping parameters for rotor dynamic analysis because the parameters affect the AMB -Rotor systems dynamic characteristics significantly.

Finite element model updating technique, which has made good progress nowadays. There has been full development in model updating and parameters identification by using modal parameters. In comparison, the FRF model updating and parameter identification, which take Frequency Response Function as objective response variables, has been applied gradually due to its many advantages：1st, avoids the identification error by modal extraction, especially in large damping parameters; 2nd, FRF contains a wealth of structure characteristic information in multi-frequency band, and is sensitive to damping and local mode.

There are rich data which can be utilized in FRF updating, but on the other side, so much information is duplicate that actually only a little of them can be used in updating. Consequently, how to select the frequency points comes to be a crucial problem. The definition of residue error is also a problem of great importance. Since most residue error of FRF are discontinuous in updating iteration which normally lead to local optimal solutions or convergence hardly.

The magnetic rotor-bearing system focused on in this paper, which has large damping which will bring in errors when identify damping in mode extraction if update by modal parameters. So the paper presents a method of model updating with FRFs as objective response to identify parameters. The two key problems, selection of frequency points and definition of residue are discussed in this paper. All the updating process was done by integrating Matlab with commercial finite element software. Finally, the identified parameters of AMB-rotor system were obtained by model updating both in simulation case and using experimental FRFs. The AMB-rotor system identified results helps to find the best way to the future research of magnetic bearing controller design and the optimization of rotor structure dynamic response. In consideration of the uncertainty of FRFs in test and finite element analysis, more work will to be done to remove or reduce the effect in the future.

Keywords: frequency response function, Viscous Damping, Active Magnetic Bearing, Finite Element Model Updating, Parameters Identification

The preparation of co-continuous micro-porous PLLA scaffolds and their application for bone tissue regeneration

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Abstract: Bone surgery is a major health concern world-wide due to the large aging population and increased occurrence of sport-related damage. A series of novel poly-L-lactic acid (PLLA) scaffolds with micro-porous structure were prepared by injection molding an immiscible polymer blend. The morphology of the produced scaffolds was observed under SEM, which shows a co-continuous micro-porous structure was successfully created. The cytotoxicity of produced micro-porous structural PLLA scaffolds was tested with culturing murine osteoblasts cell line (7F2) on scaffolds for up to 9 days; the cell morphology was assessed by fluorescent nuclear staining with Hoechst 33258. In order to evaluate the functional and cell biological applicability of the micro-porous structural PLLA scaffolds, a subcutaneous biodegradation test was performed through rat model for 1 week and 1 month time period, respectively. Our results showed that the micro-porous structural PLLA scaffolds are non-toxic, and they showed a mild foreign body reaction and complete fibrous encapsulation after implantation. Well created interconnected porous structure and biocompatibility suggest great potential of the micro-porous PLLA scaffolds in application for inducing and sustaining bone tissue repair.

Key Words: Co-continuous; Micro-porous; PLLA; Bone; Tissue Engineering

Port-based ontology modeling towards product conceptual design

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Abstract: Conceptual design plays an important role in successfully developing a new product. An effective method of conceptual design can improve product quality, reduce cost and shorten the time-to-market. This is the reason why decisions made during conceptual design can account for as much as 80% of the life cycle costs of the design. As an effective approach of modeling the components and representing their interface, port has been paid an extensive attention in product conceptual design. It is convenient to abstractly represent the intended exchange of signals, energy or material. Ontology is an unambiguous and flexible semantic specification opposite entities, and it can effectively describe the function of port. PBO has the relationship with part's connection and part environment and so on. It is the foundation which the product part concept produces, through studies PBO the function, the behavior and the structure (FBS) may further realize the product conceptual design process modeling. Firstly, from the perspective of port, we set up port ontology, and formulate the rules and pass the compatibility of the port for a multi-attribute classification. A port-based ontology is defined in terms of structure, function and behavior attribute of a product. Three knowledge layers are specialized for function, behavior and structural knowledge. We provide a formal framework to manage port ontology knowledge. Port-based design process modeling is analyzed, and port-based FBS (function, behavior and structure) representation and port knowledge management are given for product development. Secondly, one of the most common ways to represent a graph is by graph theory; otherwise we represent a graph as a binary table of the incidence function, and call the incidence matrix. PBO (port-based ontology) incidence matrix model, through analyzing the properties of connections between ports to build network connectivity model, and with the function-means tree formalized system structure. Using graph theory, PBO network model can be transformed incidence matrix and use port attribute to simplify PBO incidence matrix. At last, a simple example of probe is described. Its needs, functions, principles and structure analysis are carried out to verify the proposed approach feasibility.

Keywords: PBO, Port, Ontology, Incidence matrix, Modeling, Conceptual design

SIMULATION ANALYSIS ON THE BIONIC INTERVENTION ROBOT IN THE VASCULAR ENVIRONMENT

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Abstract: Based on the motion principle of gastropod, a novel interventional micro-injury robot which has the ability to run smoothly in the biological lumen with impulsive flowing liquid has been presented. Simulation models of the interventional micro robot in the straight and bend round blood vessels have been established with the software of Fluent. Blood flow distribution and the impact force acting on the robot by the impulsive blood flow have been simulated and calculated. All the results will provide strong proofs for the structure design and motion control of the micro robot.

Keywords: Fluent, Micro-injury robot, Simulation

Hierarchical Structure of Articular Bone-Cartilage Interface and Its Potential Application for Osteochondral Tissue Engineering

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Abstract: The artificial biodegradable osteochondral construct is one of mostly promising lifetime substitute in the joint replacement. And the complex hierarchical structure of natural joint is important in developing the osteochondral construct. However, the architecture features of the interface between cartilage and bone, in particular those at the micro- and nano-structural level, remain poorly understood. This paper investigates these structural data of the cartilage-bone interface by micro computerized tomography (μCT), Scanning Electron Microscope (SEM) and histological analysis methods. The result of micro CT shows that BMD, BMC, TMC all change greatly at the location of 2.5mm which is the interface of the subchondral compact bone and spongy bone. And the value of BMD, BMC, TMC are higher in compact bone than spongy bone. As the anther parameter of the bone density, TMD is quite different from BMD. TMD increases slowly as the location of VOI stays away from the cartilage and the value of TMD comes to a platform at the location of 4.3mm. The region from the cartilage to 4.3mm could be the place where new trabecular bones are generated, so TMD increases slowly. The fluctuations in all these plots just reflect the bones and the gaps between the bones. BVF of the bone is higher in the compact bone than the spongy bone and changes greatly at the location of 2.5mm just like BMD, BMC and TMC. BVF can reflect the porosity of the bone. histological analysis shows that the width and the angle of the trabecular bones of the joint concentrate in a certain range. The trabecular bone angles of both decalcified sections and calcified sections concentrate in 90 degree to 120 degree. The results of SEM show that There are many canals and introcessions on the surface of subchondral bone. The diameter are distributed at 10-160μm. Canals with diameter 10-50μm are more than 80%. The area of all the canals and introcessions is 7% of whole measured surface. All of the study results would be useful for the design of osteochondral construct further manufactured by nano-tech. A three-dimensional joint model with gradient porous structure is constructed in the environment of Pro/ENGINEERING software. This kind of scaffold with graded structure has three biomimetic phase, including cartilage, interface and bone. Bone phase implanted into bone cavity. The biomimetic structure of bone-cartilage interface was designed for cartilage scaffold conjunction, nutrition barrier and mechanical support. Cartilage scaffold could connect with bone scaffold by gomphosis and interlock as natural structure.

Keywords: Bionic design; osteochondral Tissue engineering; Hierarchical structure; Bone; Cartilage

Study on the Deflection and Tip Cutting Force in Needle Insertion

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Abstract: This paper summarizes a series of collaborative research projects with four visiting scholars from China conducting joint research in the SM Wu Manufacturing Research Center at University of Michigan on the needle devices.

The trend in modern medical treatment is less invasion and more localized therapy. Needle insertion is one of the most common minimally invasive surgical (MIS) procedures. Examples of needle MIS procedures include the tissue biopsy, regional anesthesia, and brachytherapy. Most needle insertion procedures concentrate on soft organs (prostate, liver, kidney, etc.), thus the accuracy of needle placement during insertion can be difficult. Besides human errors (such as fatigue of physicians and moving of patients) and limitation of the imaging devices (such as CT, X-ray and MRI), the technique errors including relative sliding of multi-layer tissues, soft tissue deformation, and needle deflection affect the accuracy of needle insertion and effectiveness of the treatment. The goal of this study is to show that the mechanistic approach can be applied to predict the needle cutting force as well as the subsequent deflection.

The process of needle biopsy is presented, and the needle tip cutting edge geometry is discussed. The cutting edge geometry of the needle can be characterized by the rake (α) and inclination (λ) angles, and a curved surface needle's rake angle can be solved according to the definition for a rake angle. Defined by Boothroyd and Knight, the inclination angle is the angle between the $\mathbf{P_r}$ plane (plane with a normal vector in the cutting direction) and the tangent to the cutting edge, $\boldsymbol{s}$. The rake angle is a measure of the cutting face angle, and is defined as the angle between two planes $\mathbf{P_r}$ and $\mathbf{A_\gamma}$, measured in plane $\mathbf{P_n}$, where $\mathbf{A_\gamma}$ is the face plane (rake surface) of the needle tip surface and $\mathbf{P_n}$ is a plane with $\boldsymbol{s}$ as the normal vector. The force on needle tip is analyzed using the Elementary Cutting Tool (ECT) method. The experimentation performed by Moore et al. showed that blades of greater inclination angle cut with less force and if the inclination angle was too low it was unable to cut the tissue at all.

Based on the analysis of the needle force, an improved cantilever beam model is presented to estimate needle deflection according to the knowledge of material mechanics. The experimental setup for studing needle deflection was bulit by Dedong Gao and C. S. McGill. The setup consists of the needle driver, a pneumatic cylinder, a force sensor (Kistler, 9256A1), a linear optical encoder (Heidenhain, LIDA 277), a guide grid, measurement stand and the phantom. To verify repeatability and reproducibility (R&R) of measurements, the range and average method is used to analyze the total measurement system variability. From the analysis results, the error is acceptable for 2 mm tolerance suggested by radiation oncology doctors who perform needle insertion in brachytheraphy. The measurements are repeatable and reproducible for the 2 mm tolerance. It is shown from the experimental results that the increasing of pressure, and therefore the needle insertion speed, decreases the amount of needle deflection and is more stabile. Howerver, the estimating needle deflection using the cantilever beam model is close to the experimental results.

Our ongoing work are studying the interaction forces between needle shaft and soft tissue and improving the experimental devices to further advance the needle deflection model.

Keywords: Needle insertion, Elementary cutting tool, Needle deflection

Metallic Foil-Assisted Laser Direct Writing of Human Colon Cancer Cells

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Abstract:

Laser direct-write technology such as modified laser-induced forward transfer (LIFT) is emerging as a revolutionary technology for biological construct fabrication. While many modified LIFT-based cell direct writing successes have been achieved, possible process-induced cell injury and death is still a big hurdle for it to be a viable technology. The objective of this study is to develop an improved modified LIFT using a four-layer structure to achieve better droplet size control and increase cell viability in direct writing of human colon cancer cells (HT-29). Human colon cancer cells were selected in this study because they (e.g., HT-29 cell) have been widely used as a research cell source to study various normal and neoplastic processes. As the HT-29 cell has retained certain characteristics of normal tissue such as hormone receptors, it has been selected as a model cell to investigate the effects of operating conditions on post-transfer cell injury.

The proposed four-layer LIFT based direct-write system was composed of a 193 nm ultraviolet (UV) pulsed laser, a four-layer structure, and a computer-controlled receiving substrate for the transferred material. The four-layer structure (also called ribbon) included a UV transparent quartz disk support, a sacrificial energy conversion layer which was also adhesive, a flexible metallic foil, and a biological material coating to be transferred. During the direct-write process, the laser pulse was directed perpendicularly through the backside of the quartz disk and focused on the sacrificial layer, which absorbed most of the incident laser energy. The absorbed energy sublimed the sacrificial layer material at the laser focal point, generating an expanding high pressure and high temperature vapor and/or plasma bubble. The bubble formation-induced pressure wave expeled the beneath biological material coating via the metallic foil, forming a cell droplet. The working mechanism herein is similar to the generation and detection of acoustic waves in liquid and solid media using pulsed lasers and the droplet formation using the piezoelectric transducer-induced acoustic wave.

In this study, HT-29 cells were transferred under different laser fluence conditions, and the viability of HT-29 cells after post-transfer was evaluated using 0.4% trypan blue stain, which is a traditional and widely employed cell viability assay for HT-29 cells. During the counting process, transparent cells were considered live while blue cells were considered dead since viable cells with intact cellular membrane excluded the blue dye. Samples from each well were counted twice to get an average cell viability value.

In summary, the effects of laser fluence on the cell number and transferred droplet diameter per laser pulse and the post-transfer cell viability have been studied using the proposed new cell direct-write technology. Some conclusions regarding this four-layer modified LIFT approach are summarized as follows:

1) The proposed four-layer modified LIFT approach is an effective cell direct-write technology and provides better printing resolution and high post-transfer cell viability comparing with other conventional modified LIFT technologies such as MAPLE DW; at the same time, the possible contamination from the laser energy absorbing material is minimized using a metallic foil;
2) The transferred cell number per laser pulse nonlinearly increased with the laser fluence; and
3) The post-transfer HT-29 cell viability decreased slightly as the laser fluence increased from 3,390 to around 6,500 mJ/cm² while significantly decreased at the laser fluences of 5,720 ± 48 mJ/cm² or higher; the post-transfer cell viability was not too sensitive as that in MAPLE DW until the laser fluence reached 4,888 ± 53 mJ/cm².

Keywords: Laser direct writing, LIFT, cell viability

Characteristic Responses of Porcine Ascending Aorta to Cutting

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Abstract: Surgical simulators are expected to have a wide use in training the novice surgeons. Design of these simulators needs information on the characteristic responses of human tissues to scalpel cutting. The objective of this study is to understand the characteristic responses and deformation behaviors of soft tissues during cutting. This study specifically focuses on cutting forces and local stiffness during tissue cutting. To realize the objective, a novel cutting apparatus is designed and fabricated, consisting of loadcells, linear actuators, and a tissue holding plate. The apparatus is capable of setting up for different initial holding forces and tissue holding distances. The study reports tissue cutting forces against initial holding force and holding distance. Local stiffness is used as a measure of deformation resistance of the aortic tissue to cutting and is reported in terms of initial holding force and holding distance. Discussion is provided to justify the experimental results based on the underlying physics and mechanics.

Keywords: Tissue, Cutting, force,

Research on Product Configuration Creative Design Based on Functional Feature Driven

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Abstract

The essence of design is innovation. The fundamental purpose of design is to achieve innovative products to meet user needs and to occupy a larger market. Pleasant and distinctive product shape innovative design is one of the important factors to win customers, and even affect the overall performance and quality of the product, for example, the shape design of an aircraft or submarine. So many scholars and experts have attracted by product shape innovative design and they have proposed various methods, and achieved remarkable fruits. Overall, these methods ignore two problems generally: (i) In the actual design process, design issues and constraints are not static, but changes with the designer's cognitive level about design objects, and the design should be considered as iterative process between design problem and solution. (ii) These methods often lack information about the function of product. Most of them produce multiple product shape and structure just through structure element operations.

In this paper, in order to solve these above problems, a creative design method for the structure of product based on functional feature driven is proposed. According to the idea that functional features determine the structure and shape of product, and then the paper present a co-evolutionary design model for the innovative structure and shape in the conceptual design stage. The proposed methods of this paper in detail are as follows:

Firstly, directed by the idea of the function of product determining the structure, and also based on the description of mapping from functional domain to configuration domain, a model of the close relationship among structures and functional features of product is established. Function is the use and performance of product which reflects the practicality of the product and is the purpose and destination of design, and also the most important attributes of product. In a sense, product design is to meet or implement the function of product. Function is the main design constraints which run through the whole process of product design, and is an important part of some design process model. Therefore, it has great significance to study how to use function to guide, constrain and shape the design activity. This paper presents a generalized feature concept of product, i.e., functional feature concept. Functional feature is not only the structure factors, but also can capture functional design information, the characteristics and attributes of the function. Then a relationship model among the structures and functional features of product is presented, and it can also be a good help to make sure functional feature-to-structure mapping is easy and feasible.

Secondly, the functional features are indispensable to be manipulated by a computer, and the functional features shall be described as formal methods using a parametric representation. Therefore, the functional requirements and design parameters are classified and formalized in terms of the functional feature set. Functional feature parameterization in the paper is not only allows model fully reflect the designer's intent, but also to quickly and easily modify the model of functional feature.

Thirdly, According to the co-evolutionary design process model offered by Maher and Poon, this paper has extended the model. The requirements of functional feature is represented as the problem space and the solution space can be considered to contain structure elements where the design process is to search the right combination of structure elements to satisfy the functional feature requirements. The co-evolutionary model highlights the co-evolution of the functional feature-space with the structure-space over time. Through searching for the possible combinatorial solution, a general co-evolutionary algorithm is introduced to generate a lot of creative configuration.

Finally, a Creative Design System of Wheel Modeling (CDSWM) is developed based on the above methodology and a design case is presented to demonstrate the feasibility and practicality of the proposed methodology. What's more, we will also look into to developing a special and combinatorial approach to support the proposed methodology in the other research fields, such as the creative design of hats or shoes.

All in all, the conceptual stage of mechanical product design has been recognized as the most critical product development stage. This paper presents a new systematic methodology for the conceptual design of product based on functional feature driven and the principles of the co-evolutionary design, the primary advantages of the proposed methodology lie in that: Not only is it simple, efficient, and can be easily manipulated by a computer, but can yield as many combinatorial solutions as possible to facilitate the creation of novel and optimal solutions, which can help designers select the optimal combinatorial solution for further development.

Keywords: Functional feature, Co-evolution, Configuration Design,

A new decision-making structure for mould due date quotation in environment of stochastic production

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Abstract: Long lead time and poor delivery reliability performance are not necessarily due to bad production scheduling. Their origin may well be wrong commitments with reference to DD made at customer enquiry stage by sales department that caused major capacity imbalances for the production system. Hence, due date (DD) quotation at the customer enquiry stage is strategically important in mould industry, having a large influence on delivery reliability performance. The purpose of this paper is to propose an effective decision-making structure for mould DD quotation in order to better manage the new arriving orders.

In mould companies, the new arriving orders can divide into two specific types: fixed DD or negotiable DD. There are five main decisions for setting DD of the new orders. (1) Identifying and rejecting undesirable orders via capacity check (for fixed DD). (2) Determining the probability distribution and mathematical expectation of DDs (for negotiable DD). (3) Adopting appropriate capacity adjustment actions. (4) Quoting DD to the customers and negotiating with them. (5) Developing or modifying production plans based on the outcome of negotiation and capacity correction actions. Based on these decisions, the decision-making structure was then proposed, which suggests different procedures for DD quotation depending on the types of DD.

For the order with fixed DD, a rough-cut capacity check procedure is firstly applied to evaluate whether corresponding resources requested by the new order are overloaded. Each resource is considered separately and the amount of requested capacity is referred to the whole relevant horizon based on an aggregate analysis of the current workload. The judgments about the fixed DD in this stage contain absolutely infeasible, could be feasible (a further analysis is needed). If the fixed DD turns out to be absolutely infeasible, any alteration of the production system is not necessary. Of course, in this case, it can be further negotiated with the customer. On the other hand, a further capacity check has to be applied. In this stage, the whole planning horizon will be split into multi time buckets. The time detailed analysis leads to implement the procedure for each resource and for each time bucket, thus highlighting timely potential overloads that could not be detected during the aggregate analysis. There are three outcomes about the fixed DD in this stage (infeasible, feasible or feasible with capacity adjustment). For the last outcome, mould companies could be interested in evaluating whether some capacity adjustment actions can be implemented before rejecting the order, such as rejecting some low priority or low acceptance probability orders and delaying some low priority accepted orders.

For the order with negotiable DD, a progress stochastic evolution (PSE) model of mould project is firstly running to determine the probability distribution and mathematical expectation of DDs. The main principle of PSE is following: it supposes that each mould project task has multi fulfilling methods. Taking the first task as the starting point, it stochastically chooses a kind of fulfilling method for each task processing in turn as far as the last task, consequently forming an evolution track. For each task in this evolution track, we can calculate its processing duration based on the capacity requirement of this task and current workload on the chosen work center. Moreover, the probability for choosing each fulfilling method is computed by corresponding transition probability matrix. We can then determine the DD of this evolution track and its generating probability. Considering all combinations of fulfilling methods of each task, it will form a lots of evolution tracks. Finally, the probability distribution and mathematical expectation of DD can be determined. Secondly, some capacity adjustment actions can be implemented based on the types of the negotiable DD. In the case of slow order, the expectation value of DD is provided to the customer, without implementing any corrective action. In the case of common order, we can adopt some corrective actions in order to advance probability distribution and expectation value of DD, without leading to extra cost. In the case of fast order, various capacity adjustments can be carried out, which it will generate many different delivery times. Nevertheless, shorter due date means the higher cost and risk. The company has to negotiate with the customer in order to select the best one.

Keywords: Mould industry; Decision-making structure; Due date quotation; Stochastic state evolution model

Research on Multistable Compliant Mechanisms: The State of the Art

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Abstract: Compliant multistable mechanisms are a special class of compliant mechanisms which possess multiple stable equilibrium positions within their ranges of motion. At these stable equilibrium positions, the mechanism can hold the positions without power input, even a small disturbance occurs. Many applications, such as switches, valves, relays, positioners, and memory cells, may benefit from a multistable mechanism.

Compliant multistable mechanisms can be roughly divided into two categories depending on the number of stable positions: compliant bistable mechanisms and compliant mechanisms with more than two stable positions. In the paper, we first review these two categories separately, and then discuss our current and future work on this topic.

Many compliant bistable mechanism configurations in the literature achieve their bistability through the snap-through behavior of buckled beams. In such mechanisms, the flexible segments undergo combined compression and bending loads during their motion from one stable position to the other. The use of tensural (tensile flexural) pivots which are subject primarily to bending and tension extends the design space for compliant bistable mechanisms. Also, the bistability of compliant four-bar linkages had been revealed.

Compared with bistable mechanisms, compliant mechanisms with more than two stable equilibrium positions have received less attention. The first compliant tristable mechanism is a symmetric Grashof mechanism (with the coupler link used as the input link). By orthogonally nesting one buckling-beam bistable mechanism in another, a quadristable compliant mechanism (provides four states of output) is realized. Oh and Kota developed an approach to synthesize compliant multistable mechanisms by connecting multiple bistable mechanisms of different load thresholds in series. COmpliant Rolling-contact Elements (CORE) have been employed to achieve multistability by having the CORE flexure to undergo different magnitudes of tension (making the flexure to store or release strain energy due to tension) at varying angular displacements.

Supported by the National Natural Science Foundation of China (Grant No. 50805110), our research group (Compliant & Precise Systems Research Group) at Xidian University is conducting research on synthesis of tristable mechanisms. Two new tristable configurations, as shown in Figure 1-2, have been developed in our recent research. Moreover, we developed two synthesis methods for designing compliant mechanisms with more than three stable equilibrium positions.

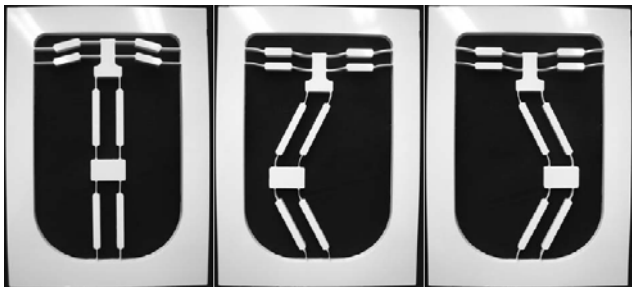
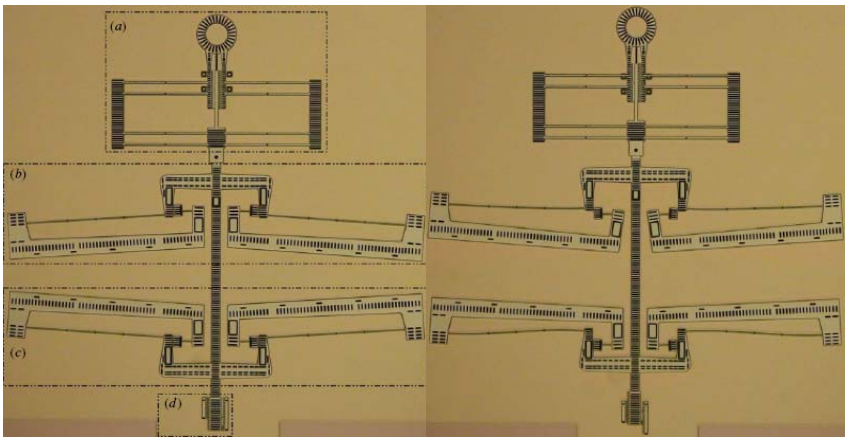


Figure 1 A dancing tristable mechanism



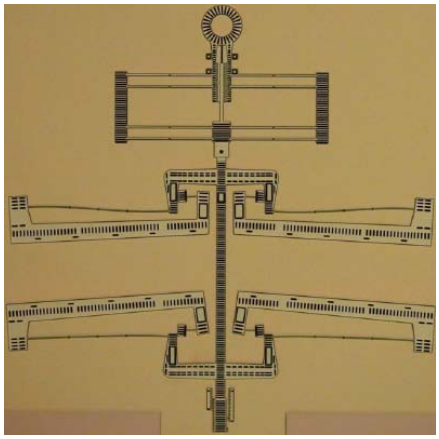


Figure 2 A double tensural tristable compliant micromechanism

Keywords: Compliant mechanisms, Bistability, Multistability

Methodology and Software for Throughput Evaluation of Complex Manufacturing Systems Using Analytical Methods

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Abstract: Computer simulation experimentations and analytical modeling based analysis are two major means on estimating the performance of complex manufacturing systems. Currently all the commercial performance analysis software systems for manufacturing systems available in the market are based on computer simulation modeling methods, which are time consuming, expensive, and requiring advanced stochastic/statistic knowledge. There is no fast and accurate computer software using mathematical methods to analyze and optimize the complex system performance in the market yet. The methodology and software we introduced in this paper are aimed to fill this gap. This paper first presents a framework of analytical modeling methods to analyze the throughput of large scale and complex manufacturing systems with unreliable machines, finite buffers, and various serial/parallel/hybrid/assembly/closed-loop configurations. Such systems are decomposed into two types of basic elements: the Or-Gate building block describing parallel/serial operations, and the And-Gate building block describing assembly/disassembly operations. By combining those two building blocks together, adjusting their interface consistency, and developing a set of advanced approximate algorithms, our analytical methods are capable of analyzing an extensive range of manufacturing systems quickly and accurately. Numerical cases show the analytic algorithm has good accuracy compared with traditional simulation models, but is thousands of times faster than the traditional simulation experimentations. Then we introduce a software system **PAMS** (abbreviation for **P**erformance **A**nalysis of **M**anufacturing **S**ystems) that implements the analytical methods and algorithms to calculate the throughputs of manufacturing systems. Numerical case studies are given to compare the accuracy between the PAMS analytical models and traditional WITNESS simulation models. PAMS is the first software system in the world using mathematical methods to analyze and optimize the manufacturing systems. It has been successfully applied to the USA BIG three auto industries and has helped saving millions of dollars on designing and continuously improving the automobile production lines in GM, Ford and Chrysler.

Keywords: Manufacturing System, Throughput Analysis, Simulation, Analytical Models

An Available-to-Promise Stochastic Model for Order Promising based on Dynamic Resource Reservation Policy

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Abstract: Facing uncertain future customer orders, a firm is challenged to make good order promising and fulfillment decisions that balance current critical resources and future customer demands, which means the firm has to allocate and reallocate critical resource dynamically to the forecast and actual customer demands in order to improve profitability. While a pull-based ATP mechanism will deteriorate overall profit especially when there exist more-profitable future customer orders, since a pull-based ATP mechanism will allocate the critical resource only to those customer orders that are already known, thus most of the critical resources are allocated to less-profitable current customer orders, which results in deteriorating overall profit. So in this paper, a dynamic resource reservation policy was proposed to prevent current less-profitable customer orders from over-consuming the critical resource. Assuming known independent demand distributions, for such a two-time-stage (current and future customer demand), three-profit group (high, medium, low profit contribution) ATP problem, a corresponding push-pull based stochastic ATP model was developed. Also the optimal reservation level was derived to maximize expected total profit by using genetic algorithm. Finally, a series of numerical experiments were conducted to reveal the important managerial insights of this policy, the simulation experiments confirmed that the optimal reservation level is positive correlated to initial availability in a low availability scenario, as for the high availability scenario, the optimal reservation level is insensitive to the initial availability. The initial availability determines the importance of enforcing this policy.

Keywords: Available-to-promise, Reservation policy, Resource allocation, Genetic Algorithm

Some improvements to the existing research on GA-based process routing optimization

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Abstract: For the problems in process routing optimization of Computer Aided Process Planning (CAPP) system, the major shortcomings of the previous process routing optimization based on genetic algorithm (GA) were analyzed and corresponding measures for improvement were put forward. The factors affecting process routing optimization such as process constraints were studied. Process digraph, as an effective process routing decision-making model, was established based on precedence constraints among operations, and which is stored in the form of an adjacency matrix. A algorithm was designed to operate the process digraph and then a number of process plans all feasible were obtained for the initial population. In order to solve the problem that some infeasible process plans generating in evolutionary process, the identification of process plan's feasibility and the repair method of infeasible process plan in the evolution process was proposed.

Keywords: Process routing optimization, Genetic algorithm, Process digraph, Constraint matrix, Repair method

Research and Application of Reconfigurable Manufacturing Execution System for China's Aviation Industrial Enterprises

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Abstract：With China's national strategy projects being successively established, such as the large aircraft and new generation of aero-engine, how to assist China's aviation manufacturing enterprise, with the help of IT, to improve the production management level and meet the changeable and individual requirement becomes a hot topic.

Firstly, based on the analysis of aviation product characteristics and production management mode, the existing problems are analyzed. Moreover, a reconfigurable manufacturing execution system (RMES) is presented and the overall aviation MES solution is given and named Workshop Manager, which takes the process route as its essence, planning and scheduling as its core, balanced production and effective throughput as its basic requirement, business process-driven management mechanism as its fundamental approach, information integration as its groundwork. It aims at the effective optimization of production process and flexible configuration of orders, processes and resources of workshops to meet their requirements and the need of changes. the function is specifically designed, and the whole production business process of Workshop Manager is trimmed and optimized, and forms the closed production process, including order reception, production planning, production preparation, job scheduling, manufacturing, quality inspection, finished product delivery, cost accounting.

Secondly, Based on the reconfigurable design idea, advanced production management mode and component technique, Workshop Manager is explored and developed independently, and is made up of over 380 function modules and 15 subsystems: production plan management, job-shop scheduling management, production monitoring management, inventory management, tool management, quality management, equipment management, cost management, document management, assistant decision support, interaction Kanban management, data acquisition management, workshop website, basic production data management, software privilege management. Not only can each subsystem of Workshop Manager function individually, but also can be combined with other subsystems or their module together to customize a new system according to the workshop actual demand. All modules of Workshop Manager cover almost the whole operation and management contents of the production workshop, and realize the scientific and organic integration of materials flow, capital flow and information flow of the production workshop.

Moreover, a four-tier MES architecture based on SOA is established to make Workshop Manager have a good reusability and expansibility. The presented component hierarchical architecture solves the component hierarchical clustering and grain size problem. Each component of different layer is encapsulated successfully and further assembled according to their own individual business processes, different user interface, data description form and report form. Afterwards, an information integration of workshop manager with other hardware and software systems, such as barcode scanner, RFID, PDA, on-line measurement, CAPP, ERP/MRP Ⅱ and PDM is discussed in details.

Finally, the Workshop Manager is developed successfully by employing component technology. Until now, Workshop Manager has been applied to more than 30 job-shops in 7 large and middle-sized enterprises of China, such as XAC, XAE, and has brought about significant economic and social benefits. Especially, the overall application scope and benefit of Workshop Manager in XAE keep the leading position in China. The application results have confirmed that the integrated and reconfigurable Workshop Manager is feasible and will be rather effective, and is suitable for multi-item and small-batch production mode, and can been widely applied in aviation, aerospace, shipbuilding and equipment industries.

Keywords：Reconfigurable Manufacturing Execution System (RMES), Production Planning and Control (PPC), China's aviation industrial

Structural Design and Simulation Analysis of Machine Tool for Stranded Wires Helical Springs

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Abstract: Stranded Wires Helical Spring (brief name as stranded spring) is a cylindrical helical spring formed from several steel wires by tied up to be twist into a helical spring. Taking advantage of its predominant characters such as better stiffness, higher strength, longer fatigue life and more effective shock absorption compared with single-wire helical spring, Stranded wires helical spring has important application in the shock absorber of the automobile instruments, the armament blast-off system and aeroplane engine etc. Furthermore, it also has important and potential value in civil use.

However, its wider use is limited to some special fields by its high structure design requirement, complicated manufacturing process and difficult quality control. Big machining error, low product precision and high rejection rate (which is even to the point of 80%) always occur owing to the incorrect modeling of the mathematical model and unreasonable design of the machine, rendering the tough further research and high manufacturing cost of this particular spring.

Previous mathematical model of closed-end spring requires complicated programming tasks and can't guarantee the processing accuracy, even worse, conventional processing method or current numerical control machine consumes a long-time machining cycle and tediously manual work, such as long time taken up by drawing wires, frequent twist-off of the wires during processing for the defective machine design and ineffective tension control system.

On account of its high design requirement and complicated manufacturing process, and aiming at overcoming the defects mentioned above, this paper establishes a mathematical model of closed-end spring, The simulation of the centre line and its expanding model are carried out by PRO/E. Compared with other previous mathematical models, the result corresponds to the design and actual processing requirements obviously, realizing parametric modeling of closed-end stranded springs as well.

To realize four-axis simultaneous motion among the middle-layer twisting shaft, outer-layer twisting shaft, turn-screw and reeling shaft, on the basis of the manufacturing principle and machine structure, the whole system adopts PC+PLC control structure to solve the synchronization control of the four servomotors during reeling, which includes host computer (PC), PLC module, the actuators (servo drivers and servomotors), the controlled objects (five shafts) as well as the cables between them for transferring data.

According to the processing characteristics and modeling of closed-end stranded springs, a novel scheme design scheme for the manufacturing machine is provided, which has overcome the drawbacks of the traditional machine and previous numerical control machine. Then, for the sake of appraising the feasibility of the machine design and the machining characteristics of the machine, feature modeling, virtual assembly and motion simulation are carried out in the environment of PRO/E. Regarding to the structure complexity and multitudinous components of the machine, by using animated technique and simulating analysis function of PRO/E, mutual interference between moving machine components can be checked efficiently. During the simulation, the whole process of machining can be shown in 3D view, the results of which show that this scheme is valid in aspects of parts shape design and satisfaction in the kinetic requirements. In addition, by 3D motion simulation, the machine's motion and the design validity of the closed-end spring are verified. Finally, a Human-Machine Interface is proposed to realize the communication between the motion control system and the host computer.

Keywords: Closed-end Stranded Wires Helical Springs, Structural Design, Motion Simulation

Modular Design Method for Reconfigurable Machine Tools

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Abstract

In a bid for higher competitiveness, the thought Make to Order (MTO) becomes more acceptable to manufacturing companies. In order to meet the needs of multi-products and variety batch production, not only should the manufacturing system processes certain rigidity and appropriability to guarantee the productive efficiency, but also can quickly enhance its ability of equipment manufacturing without investing a great deal in devices.

In order to adapt to the unpredictable, fast-changing market and global market competition, reconfigurable system (RMS) has been put forward. Reconfigurable machine tools (RMT) are the core foundation of RMS hardware devices. Based on the characteristics of RMT and analysis to mapping relationship of the products function, structure and the relativity of products accessorial function, the module partition meeting the needs of RMT design has been studied. Further more cluster the characteristics of product and process step. Design for an operation family is the essence of RMT design, when the process needs change, RMT can quickly, economically transform the software and hardware. RMT transform its' produce ability without reducing accuracy. With the design limits, RMT can be cost-effectively converted when the requirements change for RMT is designed for a specific, customized range of operation requirements.

In this paper, module division for RMT has been studied. Relatedness matrix was set up in order to establish the machine module and analyzed the front and back contrasts, a optimal model of RMT can be set up which can performance better and reach the minimal cost.

The reconfigurable machine tool has not been definitely defined yet. Document writes the modular design method of machine tools is the key factor of its reconfiguration, and the reconfiguration will be realized by removing, adding or replacing the machine tool or the units and modules of the its system. Compared with the most common machine center, the reconfigurable machine tool has its own features.

The module division of the reconfigurable machine tool is the basis of modular manufacturing. Every module has its own functions and is universal to some extent. The modules which have connections has corresponding interface features. They should also meet the demonds of location and movement among all the modules. Analysis the relationship between the process and machine modules, and map the function requirements and design parameters.

the key techniques of the reconfigurable machine tool's design method base on the modularization, and constructs a human-computer interaction reconfigurable machine tool's prototype system which is compatible to the parametric design and the transfer of the database information. The system's validity is validated by an instance. At last, set up the method for the analysis of dynamic characteristic of machine tools. The research results have been applied to production practices, with good effect, and it meets the requirements for rapid change of customers' needs.

Keywords: Reconfigurable machine tools, module design, performance analysis

Shape Compensation of the Molding Dies in Glass Molding Press for Aspherical Lens

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Abstract:

Aspherical lenses are widely needed in the optical system, which have many more excellent optical characteristics than spherical lenses. Glass molding press (GMP) process has been applied to produce aspherical glass lenses in mass production. Due to the mechanical deformation of the molding die during press and the different thermal expansion and contract between the molding dies and the glass in the GMP process, even if the molding dies was exactly machined with the same surface profiles as the designed aspherical lens, a large forming error would occur after GMP. Therefore, the molding dies should be compensated. So far, the compensation of the molding dies has been conducted by repeated trial-and-error experiments and measurements.
In this research, the finite element methods (FEM) simulation is extended to study the compensation of the molding dies in the GMP process for aspherical lens. The four stages, heating, pressing, annealing and cooling of the GMP process for aspherical lens were simulated by the finite element method (FEM). The mechanical deformation and the thermal deformation of the molding dies and the glass were precisely simulated.
Based on the simulation results, the shape of the molding dies was compensated and applied to the GMP experiment. The molding conditions were set at the optimal condition obtained by the FEM simulation. The molding temperature is 570°C and the pressing rate is 6 mm/min. Furthermore, by applying the compensated molding dies to the GMP experiments, the form accuracy of the molded aspherical lens was successfully controlled within 0.26 μm. The improvement of the forming accuracy of the molded lens verified the validity of the simulation results. In this way, a method to compensate the shape of the molding dies in GMP for aspherical lens was confirmed.

Keywords: Glass molding press, Aspherical glass lens, Finite element method, Molding die, Compensation

Retrieval of Residual Stress Field for Predicting the Machining Deformation

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Abstract: The unknown and uneven residual stress in blanks will cause deformation on large scale part, especially for large scale non-prestretched plates. This article discusses the retrieval of local residual stress field in each layer of non-prestretched plate and the modeling of the 3D stress field of plate based on local stress fields. We put forward a function of the stress in non-prestretched plate and use the spline, bilinear and bicubic arithmetic combined with a specially designed array of measurement to interpolate the local stress field. The results of the retrieval simulation show that the spline method is more precise than others. The serried array of measurement can improve precision, and the high grads of stresses have the reverse effect. The force and moment equilibrium equations are established to calculate the stress in the reserved layers. The profile deformation can be predicted by machining simulation with the 3D field as the initial condition. The experimental results show that the structure of parts and the distribution of stress determine the deformation. The predictive deformation is close to the real one. The maximum relative error is about 15% mainly induced by high level stresses and more measured layers can reduce the relative errors.

Keywords: Machining deformation, Residual stress, Stress field retrieval

Modeling of CDM and Analysis on the Differences between CDM and HDM

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Abstract: The 50th percentile Chinese dummy model, CDM, was developed based on the anthropometric of Chinese people by scaling the Hybrid III 50th percentile dummy model, HDM, in MADYMO software. The CDM was validated by lower speed sled frontal crash tests with a volunteer. In order to investigate the response differences of CDM and HDM, the frontal crash responses of different dummy models in different restraint systems were analyzed. In addition, seat stiffness, belt stiffness and belt anchorage position of restraint system model were changed to investigate their influence to the responses of different dummies. The results show that the response is obviously different between CDM and HDM in the same or similar impact circumstances. The head and neck injury parameters of CDM are obviously larger than those of HDM, and the changes of the responses of these two dummy models are also different when the restraint system parameters changed.

Keywords: Anthropometrics of Chinese people, Dummy model, Volunteer test

Integration of CAD and CAM in Manufacturing Automation

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Abstract: A Mechanical Engineering advanced course in Manufacturing Automation has been developed with the overall objectives to integrate Problem Solving, Computer-Aided Design and Computer-Aided Manufacturing into an integrated entity – Computer Integrated Design and Manufacturing.

Keywords: Integration, Problem Solving, Design, Manufacturing, Automation.

Atoms Structure Study of the Initial Stages of Diamond Deposition on Cluster Models for 6H-SiC (0001) Surface

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Abstract: Diamond films exhibit unique mechanical, thermal, optical, electrical properties and excellent chemical stability, as well as the superhard coatings for cutting tools. The chemical vapour deposition (CVD) diamond layers are recognized as the best candidate for the protective coatings. In addition, silicon carbide ceramics have been studied extensively because of their potential use for mechanical and tribological applications. It has been found that the fabricated diamond coatings on the SiC substrate can enhance the tribological properties by making more excellent mechanical and tribological materials on the surfaces. However, the mechanisms of the interface with diamond nucleation on SiC surfaces have been seldom studied. Recently, it has reported that the behaviour of different reconstructed 3C-SiC (100) surface after Microwave Plasma (MPCVD) exposure has been addressed, which has encouraged the progress towards intensive oriented diamond film preparation on SiC surfaces. The present study focuses on the mechanisms at the SiC/diamond interfaces. Certainly, it is noted that knowledge of the initial stages of depositing diamond on SiC surfaces is a significant result which contributes to understand a number of film properties including optical, electrical, acoustic, magnetic and mechanical properties.

The aim of this paper is to investigate the reconstructions in the initial stage of the diamond growth deposited on the 6H-SiC (0001) surface via first-principles calculation. Various types of structures with different number of carbon atoms covered with and without H-presence are conducted to evaluate the stable reconstructions in the process of diamond growth by CVD, which could thus be applied to determine the favourite nucleation and growth and estimate the possible interfacial structures. The six types of reconstructions are conducted on analysis of the diamond growth, which include fully hydrogenated surface, full carbon-covered surface, 1/2 MLs carbon atomic absorption surface with a *row* of C replacing H, 1/2 MLs carbon atomic absorption surface with a *column* of C replacing H, 1/2 MLs carbon atomic absorption surface in the direction of surface *cross* rows, and 1/4 MLs carbon atomic coverage surface. The calculated geometry optimization and their structural energies reveal that 6H-SiC (0001) surface with fully H-presence are favorable for the diamond growth. The diamond deposition of directional selectivity tends to the *cross* orientation. For the surface reconstruction with dangling bonds, the graphite is likely to develop fast on the 6H-SiC(0001) surface layer in the initial of 1/4 C MLs structure. Finally, the chemical potential analysis is employed in order to compare the stability among phases with different plenty of C-coverage on the 6H-SiC (0001) surface. The stability of various adsorptions on different number of carbon atoms coverage, as a function of C chemical potential, are also performed in the analysis of the calculated results. The calculations indicate that, for all of the 1/2 C MLs structures with H-presence, the 1/2 C MLs *cross* structure is the only one favorable stability of surface reconstruction in the process of the initial stage of CVD diamond growth. The surface reconstructions with dangling bonds have the 1/2 C MLs *cross* and *row* structures. The results collectively illustrate that increasing the hydrogen bonds to the 6H-SiC (0001) surfaces is attributed to form the stable CVD diamond formation, which throw some light on improvement of the technological parameters involved.

Keywords: Cluster model, Diamond deposition, First-principles, Chemical potential

Performance Analysis of Journal-thrust Floating Ring Hybrid Bearing with Independent Oil Supply

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Abstract: Externally pressurized hydrostatic/hydrodynamic bearings have become increasingly popular in many super high speed machines such as astronavigation, generators and high speed maching tools due to their remarkable characteristics in respect of low friction, high accuracy, long life, smooth operation, high fluid film stiffness, damping capacity etc. Adopting floating ring hybrid bearing is the effective method to increase the rotational speed of rotor-bearing system. Among most floating ring hybrid bearings in common use, the external restrictors are used and the oil is supplied both to the inner fluid film and the outer fluid film. Therefore the external restrictors are easy to be plugged and the inner and outer oil supply pressure can not be adjusted independently. The performance of bearing can be controlled if the oil is supplied respectively to the inner and outer fluid film independently. How to design the new structure floating ring bearing and how to build the model and analyze the influence of parameters on bearing characteristics is the base to improve the bearing performance.

This paper presents a theoretical study concerning the static and dynamic performance of hybrid journal-thrust floating ring bearing with inner and outer fluid film independent oil supply. A new structure fluid lubricated floating ring hybrid bearing with independent oil supply compensated by flat capillary restrictors is designed. Bases on laminar current theory, the equations governing the flow of inner and outer fluid film in the journal-thrust floating ring bearing are established. The variation regularity of static and dynamic performance with oil supply pressure and rotational speed are analyzed with finite element method (FEM) simulation.

From the FEM simulation, it is shown that all static characteristics coefficients increase rapidly with the rotational speed increment under the same supply pressure. On the other hand, except for flow volume rate, other static characteristics coefficients increase a little with supply pressure under the same rotational speed. It is clear that the fluid film hydrodynamic effect is stronger than hydrostatic effect when the rotational speed is over 3000 rpm. Meanwhile, the variation of oil supply pressure does not influence the balance of floating ring under the same rotational speed. It is shown that the dynamic characteristics absolute parameters increase quickly with the rotational speed increment under the same fluid supply pressure. While under the same rotational speed, the dynamic characteristics absolute parameters vary obviously with the fluid supply pressure increment.

In conclusion, the static characteristics coefficients are not sensitive to oil supply pressure, but the dynamic characteristics parameters varies obviously with oil supply pressure. Those conclusions give theory base to control the stability of floating ring hybrid bearing on line through adjusting the oil supply pressure. The research fruits in this paper have important value to guide the design of floating ring bearing.

Keywords: Journal-thrust bearing; Floating ring; Independent oil supply

Thermo-Elasto-Plastic Coupling Finite Element Analysis of Rail during Wheel Sliding

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Abstract: As it is known, when the traction or braking forces exceed the available adhesion of wheel and rail, the gross slipping occurs. The wheel-rail sliding contact may lead to friction heat that causes a temperature rise in the surface layer high enough to result in metallurgical transformation of the wheel-rail materials. And cracks often initiate easily in the transformed layer. With the development of heavier axle loads, greater traffic density and higher train speed, thermal damage becomes an increasing problem in recent years. To study the behaviors of wheel-rail rolling contact fatigue and failure, it is necessary to investigate stress and temperature fields of wheel-rail during wheel-rail sliding contact. Few numerical researches have focused on the temperature and stress distributions of wheel-rail sliding contact with the contact method. The present paper uses the elastic-plastic finite element contact method to simulate wheel-rail sliding contact and investigates the stress and temperature fields of rail during wheel sliding on rail.

In this paper, a two-dimensional thermo-mechanical coupling plane strain finite element model of wheel-rail sliding contact is established by using the commercial finite element package ANSYS. In the model, the heat-convection between the rail and ambient and temperature-dependent material properties are taken into consideration. The effect of a time-dependent heat-partioning factor on temperature rise is also investigated. A bilinear kinematic plastic material model is used. To eliminate the influence of boundary conditions on the results, the rail is modeled by the length of 1000 mm and height of 172 mm. The bottom and two ends of the rail are assumed to be insulated and fixed. A flexible-flexible contact pair is used to simulate wheel-rail contact. The mesh model consists of 92760 plane-strain elements, 1128 contact elements, 874 target elements and 93937 nodes. In the present numerical analysis, a freight car wheel with load W = 21 t, radius R = 420 mm and the type of LM worn profile is selected. The rail type is CHN60 of China. The coefficient of friction between the wheel-rail contact is assumed to be 0.3. The sliding speed of wheel is assumed as 1 m/s. The temperature field distribution of rail can nearly reach a steady state after three length of contact patch of wheel sliding on rail. Therefore, to save time, the present paper only calculates the six length of contact patch of wheel sliding on rail. The x (longitudinal) direction constraint of wheel is used to simulate the wheel sliding on rail. A pressure is applied on the lower half of the wheel's inner circle to simulate the wheel's load. And the frictional heat generated by wheel-rail friction can be calculated by the software ANSYS.

When considering material's plasticity, the contact area length of FEM results is larger by 4mm than that of Hertzian results, accoding to the comparison of the two methods. To make the analysis more realistic, it is necessary to consider the material's plasticity of wheel and rail. The Von Mises equivalent stress and temperature distribution results of rail near the contact area, after the temperature field reaches the steady state, show that the maximum stress happens at the small area on the contact surface. We can also see that the temperature rise affected zone exists in a thin layer of rail surface with about 2.0 mm.The temperature history of different depth rail material shows that the surface temperature starts rising rapidly and reaches the maximum value when the wheel slides for about 1.5 length of contact area. Similar trend happens to subsurface material, but the temperature decreases with increasing depth. The time when the maximum temperatures of subsurface material occur is late due to the heat conduction between surface materials and subsurface materials needs some time. The shear strain and equivalent plastic strain histories of different depth rail material show that the time point for maximum shear strain is the same as that of temperature. The maximum equivalent plastic strain of surface material of rail is larger than that of subsurface material by 93.4%. It is because that the temperature of surface material is higher than that of subsurface material. And the effect of temperature on the material properties is obvious when the temperature is high. Therefore, surface failure of rail material is likely to occur due to the influence of thermal stress. The current investigation also indicates that the effect of the varying heat partition factor on the temperature field is not significant.

Keywords: Wheel-rail sliding contact, Thermo-mechanical coupling, Finite element method

Fabrication of Micro Dent Arrays on the Titanium Surface by Laser Shock Peening and Characterization of the Tribology Functionality

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Abstract:

The controlled patterning of solid surfaces improves the wear, friction and lubrication [1]. Micro dents serve as fluid reservoirs that may effectively retain lubricant. Also micro dents function as traps for wear debris, eliminating a potential plowing effect caused by entrapped particles. The long-term benefit of surface patterning is to extend the life of contacting surfaces. Micro dents on the surface can improve the surface lifetime by a factor of ten [2]. Experimental studies on the effect of dent patterns on micro-grooved sapphire discs lead to the conclusion that the fabrication of micro dents on metallic surfaces is a useful method to reduce friction in sliding contact. Manufacturing techniques to fabricate micro dents arrays on component surfaces include micro indentation [3], micro-drilling [4], and laser ablation [5]. However, these processes often induce surface damage such as cracks and phase transformation which may significantly shorten component life. A new process to make dents while avoid material damage is highly needed. This study presents a practical fabrication technique that combines production efficiency and enhanced surface integrity to avoid the above issues.

Ti-6Al-4V is the most commonly used titanium alloy in manufacturing aerospace, biomedical, marine and power generation components. However, surface contact applications of Ti-6Al-4V are very limited due to the pronounced galling tendency. In this paper, the use of LSP along with an automatic X-Y table proves to be an attractive and reliable method for producing micro dent arrays with enhanced surface integrity and free of cracks. Shallow micro dent arrays with high compressive residual stress and increased microhardness on polished Ti-6Al-4V have been successfully fabricated.

Micro dent arrays have been fabricated on titanium surfaces by laser shock peeing. The surface topography, surface integrity, and tribological performance of the fabricated micro dent arrays have been characterized. Key findings of this research are:

- Micro-scale laser shock peening is capable of fabricating micro dent arrays of different density.
- The peened surface has increased micro-hardness by 15% due to strain hardening and size effect.
- LSP produces high compressive residual stress on the surface. A gentle post polishing makes the residual stresses on peened surfaces more compressive.
- The 10% density of micro dent array reduces coefficient of friction by 18%, while the 20% dent density increases coefficient of friction by 17%.

Keywords: **Surface patterning, micro laser shock peening, surface integrity, tribology**

Tool Wear of Turning Hydrogenation Ti-6Al-4V Alloy

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Abstract:
Titanium alloys have been widely used in the aerospace, biomedical, automotive and petroleum industries because of their good strength-to-weight ratio and superior corrosion resistance. However, it is very difficult to machine them due to their poor machinability. Due to their low thermal conductivity, high chemical reactivity and low modulus of elasticity, together with the effect of abrasive, adhesion, diffusion and oxidation, which gives rise to the crater wear of rake face and the wear land of flank face. If the tool wear is too quickly, the tool cost will be high, and it will affect the machining quality of workpiece and decrease the productivity. How to reduce the tool wear and the cost has become one of the primary problems in machining titanium alloys.

In order to research the tool wear regularity in machining titanium alloys, some scholars have done a great deal of cutting tests by means of hydrogenation before machining. Although they have acquired some valuable achievements, the influence of hydrogen contents on the tool wear regularity have been less investigated extensively. The present investigation is an attempt to research the influence hydrogen contents on tool wear regularity in turning hydrogenated Ti-6Al-4V alloy, with analysis and discussion.

Keywords: Titanium Alloy, Hydrogenation, Crater Wear, Flank Wear

Reviews on the Drilling of Carbon Fiber Reinforced Plastics (CFRP)

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Abstract: With the development of composites, large scale of composites has substituted for conventional materials in many fields due to their unique mechanical properties, including the fields of aeronautics and astronautics, automobile, etc. Carbon fiber reinforced plastics (CFRP) are characterized by low density, superior specific strength and specific stiffness, low expansion coefficient, high fatigue strength, good thermal shock resistance, high heat resistance and vibration reduction.

The CFRP composites are generally fabricated by various processes such as hand lay-up, autoclave, filament winding etc. Nevertheless, the particular characteristics of composite materials drive their machining behavior and the machining mechanisms to be distinctly different from the homogeneous materials. CFRP need to be machined to facilitate the dimensional control for easy assembly and functional aspects. Drilling is one of the most common machining processes used to install fasteners for assembly of laminates.

In order to reduce the common drilling defects, such as delamination, carbon fiber pullout and extend the tool life, many researches are carried out in composite cutting mechanism, tool materials and geometry, processing technology, and drilling quality evaluation.

Keywords: CFRP, Drilling, Review

Sequential Monitoring of Surface Spatial Variation in Automotive Machining Processes based on High Definition Metrology

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Abstract: The ability to monitor machining processes within micron level is critical to high precision manufacturing. New non-contact measurement technology, such as holography based high definition metrology (HDM), makes this feasible through monitoring of both the part shape and its surface texture. However, conventional statistical process monitoring and diagnostic schemes based on low definition measurement technology have limitations in addressing the HDM data since such data are in high-dimensional form and may show strong spatial correlation. Based on a previously published sequential strategy for global and localized monitoring of shape variations in HDM data, this paper improves the method by refining the localized monitoring scheme, and applies the method to HDM data collected from an automotive engine head machining process. The results show that the developed HDM monitoring scheme can effectively localize the defective regions on the out-of-control parts.

Key words: Sequential process monitoring, High definition metrology, Automotive engine head

Effects of Harmonic Current on Dynamic Performances of High Speed Motorized Spindles

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Abstract: In order to study the effects of harmonics on dynamic performances of high speed motorized spindles, the formulae for the harmonics are deduced according to the mechanism of harmonic currents. On the basis of the principle that the effects of three-phase symmetric currents on the performance of spindles can be added linearly, it is obtained that the effects of each harmonic current on dynamic performance of high speed motorized spindles comply with the principle of linear superposition. With the superposition and the T-I equivalent circuit, the form of harmonic current application is concluded, and the oscillating harmonic torque generated from the harmonic current is deduced. According to the formulae for calculating oscillating harmonic torque and torque ripple, the impact of every order harmonic current on high speed motorized spindles' performance is quantized, which can be referred as the basis for analyzing the torque and speed ripple amplitude when analyzing the interaction between the harmonics and the power frequency. Therefore, those harmonics that need to be curbed to enssure the precision of the high speed motorized spindle, as they have significant influences on spindle's dynamic characteristics, can be clearly identified. Then, harmonic interferences for a 170MD15Y20 high speed motorized spindle with different rotating speeds are tested on a dynamic performance testing platform for the high speed motorized spindle. The results show that the higher the order of the harmonic current, the smaller the amplitude of the oscillating harmonic torque produced by the high order harmonics, thus exerting less impact on the high speed motorized spindle's dynamic performance. On the contrary, the lower the order of the harmonic current, the larger the amplitude of the oscillating harmonic torque produced by the high order harmonics, thus having more influence on the spindle dynamic performance. As each harmonic current frequency of is integral multiple of the basic frequency and the spindle's synchronous speed is proportional to the resource frequency, it can be verified that when the spindle speed increases, the orders of harmonics that need to be curbed decrease,and that while the spindle speed decreases, the orders of harmonics that need to be curbed increase, making it is impossible that spindles are operated at low speed, thus limiting the scope of spindles' speed

Keywords: High speed motorized spindle; Harmonic current; Equivalent circuit; Torque ripple; Dynamic performance

AN EXPERIMENTAL AND NUMERICAL ANALYSES OF HARD TURNING AISI 440C MARTENSITIC STEEL

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Abstract: AISI 440C martensitic stainless steel with high chromium and carbon elements has superior mechanical properties and can be heat treated to the highest hardness among the corrosion resistant steels. Thoroughly hardened AISI 440C martensitic steel has been widely used in various engineering applications such as steam and water valves, pumps, turbines, compressor components, shafts, cutleries, surgical tools, aerospace bearings, and plastic moulds. However, hardened AISI 440C martensitic stainless steel is a typical difficult-to-cut material due to its high hardness, high strength at elevated temperatures, rapid work-hardening, and chemical reaction with most tool materials. This paper introduces an experimental setup of hard turning AISI 440C martensitic stainless steels (HRC 55). Then, the effects of cutting conditions of cutting speed, feed rate, and depth of cut on cutting forces are investigated. Lastly, a 3D finite element modeling of hard turning has been developed and a comparison between measured cutting forces with the predicted data is made.

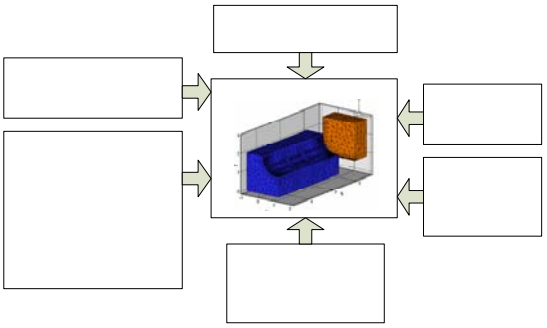

Fig. 1 Finite element mesh of 3D turning and flow chart

The turning experiments were conducted on a CNC turning lathe. AISI 440C stainless steel was heat treated by induction hardening to 55 HRC. The CBN10 grade tool insert, SECO CNGA 120408S-L0 with 0.8 mm nose radius, was used in this study. The cutting experiment was designed based on the Taguchi method which is one of the fractional factorial designs. Three cutting speeds (120, 150, and 180 m/min), three feed rates (0.1, 0.15 and 0.2 mm/rev), and three depth of cuts (0.1, 0.3, and 0.5 mm) are conducted. All cutting tests were conducted in dry conditions, i.e., without coolant.

A machining simulation software AdvantEdge 3D was used to model the turning process. The simulation flow chart is shown in Figure 1. The predicted tangential, radial, and axial forces are compared with the measured data (see Fig.2). The model predictions generally over-estimate the forces. The discrepancy ranges from 4.8% to 24.5%. Despite the existence of discrepancies, the measured force components validate the model prediction in a certain way. It also indicates that the model accuracy could be further improved. The force discrepancies may be contributed by several factors such as the inaccuracy of the material properties and constitutive equations and the simplified friction model. As a result, the simulation results can be considered as force trends for guiding machining operations.

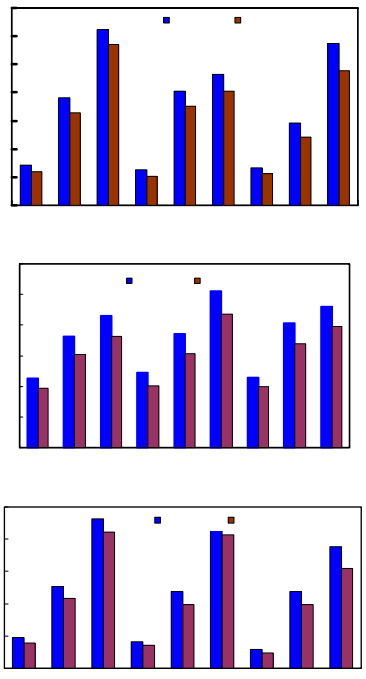

Fig. 2 Force comparison between the predicted

Keywords: AISI 440C martensitic steel, hard turning, Taguchi method, cutting force, FEA

Mechanical Strength Characterization for Silicon-to-Silicon Direct Bonding

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Wafer direct bonding technology is a process of adhesion of two flat and clean mirror wafers without using intermediate layers. Many different materials or complicated 3D structure, such as SOI wafer and Microfluidic channels, can be achieved by the technology. The bonding quality can be measured from the bonding strength and the bonded area(the amount of voids). Generally, the most references which refer to the wafer bonding only gave the bonding strength value without pulling speed.

In this paper, six double side polished (100)P-type wafers were used. Three pairs of wafers were examined in three groups with different chemicals and pretreatment time. Two cleaning method have been implemented. The first method was only to use the piranha solution to clean for group 1. piranha solution can remove the organic contamination effectively and the surface of the wafers can thicken the silicon native oxide layer. The second one was used the SC1 solution after the piranha solution to clean for group 2 and 3.

Table 1 Samples by different cleaning process, Group1 is only cleaned by piranha solution; Group 2 have a SC1 after the piranha solution pretreatment

GroupID	Chemical	Temperature (°C)	Pretreatment times (Min)
1,2,3	4parts98%H_2SO_4 1Part 30%H_2O_2	120	15
1,2,3	DI water	45	5
1	DI water	room	5
2,3	1part $NH_3 \cdot H_2O$ 1part 30%H_2O_2 5parts H_2O	75	15
2,3	DI water	45	5
2,3	DI water	room	5

Then, Each group of pretreated wafers were put in to bond by AML-AWB04 bonding machine. The force was added up to 1500 N under the pressure of 1e-4 mbar within 2 min. After the pre-bond process, According the bonding mechanism mentioned before, the annealing profile was arranged as the fig. 1 shows. The temperature maitained at 300°C, 800°C and 1100°C for a period in order to allow the reaction to proceed completely during the different step and to form the strong Si-O-Si bond.

Finally, the results measured from the IR transimission and tensiles test will also be discussed and the pulling speed effect to the tensile test is investigated. The bonding strength of the SC1-cleaned samples is about 5.4MPa with partially crack but no more than 0.7MPa for the only piranha solution cleaned sample. The pulling speed effect to tensile test was also investigated. The results show that the pulling speed effect should be considered during the tensile test.In comparison of cleaning between piranha solution only and SC1 after piranha solution, we found that high bonding quality is attained by the latter cleaning process. The subsequent high temperature annealing profile is proper to the need of whole bonding process. The tensile test results show that group 2 and group 3 have high bonding strength. Although the bonding strength are only 5,4Mpa ~9.1MPa, we have reason to believe that the measured values of bonding strength can be higher if the glue is fine. In the tensile test, the pulling speed is one of the essential parameters. Different pulling speed will lead to different results. So it is needed to make further research to the relation between the bonding strength test results and pulling speed.

Keywords: Wafer Direct Bonding, Standard Cleaning, Tensile Test, Pulling Speed

Deformation Behaviors of the Superconductor-silver Interface during the Rolling Process of Bi-2223/Ag Tapes

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Abstract: Analytical model of interface deformation behavior during rolling process was established to investigate the principle of sausaging formation. Formula between the compressive stress, internal pressure from powder, material property and physical dimension was derived based on silver layer using energy approach. Moreover, the curvature difference of interface before and after deformation was defined as evaluation factor for the interface forming quality. Numerical model of Bi-2223/Ag high temperature superconducting wires during rolling was proposed, and the effect of process parameters such as inner tube material, roller diameter and friction coefficient on the deformation behaviors of the interface in Bi-2223/Ag wire was analyzed. The results show that inner sheath material with high strength can lead to a better silver-super interface, meanwhile, larger roller and small friction coefficient can reduce the interface instability and obtain the final tape with high critical current density (J_c). Furthermore, the numerical results verify the accuracy of the theoretical derivation.

Keywords: Interface, Sausaging, Bi-2223/Ag, Modelling

Research on Particle-wall Adhesion of Four Kinds of Emitters

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Abstract: Particle-wall mechanical model was used to study the adhesion character of four kinds of emitters: zigzag labyrinth channel, trapezoidal labyrinth channel, Special-Shaped I labyrinth channel (SS-I), and Special-Shaped II labyrinth channel (SS-II). The simulation was performed with the software FUENT which provides the possibility to implement several subroutines for additional forces or models through user defined functions (UDF). The spatial distribution of adhesion position of particles was showed by MATLAB software. The particle velocity at the inlet was assumed to be equal to the value of the fluid velocity. The interaction between the discrete phase and the continuous phase was not considered for low particle concentration in emitters. The Fluent software provides two methods to consider the effects of turbulent which were stochastic tracked and cloud tracking. We used the stochastic track method to consider the turbulent dispersion and the effect of "try" number on the simulation results was investigated. And the results show that when the "try" number was set as 10 the variation for η was less than 0.02. So we used 10 tries each to simulate the particle-wall adhesion. A variable, adhesion probability η, was proposed and was equal to the number of injection divided by the number of particle which adhered to channel wall. The effect of diameter of particles on particle-wall adhesion was investigated. The simulation results showed that the smaller the particle diameter is, the easier particle-wall adhesion happens. And when the diameter is between 1 and 10 μm, adhesion probability changes obviously; when the diameter is more than 10 μm, adhesion probability changes slowly. Comparison of the adhesion probabilities in different channels shows that Trapezoidal channel and SS II channel have good performance of anti-adhesion of particles. We established a PIV platform for visualized experiments on particle-wall adhesion. The micro-channel test pieces were fabricated by laser rapid prototyping technique, and a glass cover was bonded to seal the channels. It was found that the adhesion phenomenon changed significantly at 40min of the experiment. And washing the channel can make some particles which were trapped by channel wall to detach from the wall and flow along with water. The spatial distribution of adhesion position in four kinds of emitters was investigated and the analysis and comparison of the results of simulation and visualized experiment were carried out. The visualized experiments verified the effectiveness of the particle-wall mechanical model. We used the pressure loss coefficient(PLC) to evaluate the hydraulic performance of emitters and the bigger the PLC number, the better hydraulic performance of emitter. Comprehensive consideration of hydraulic performance and anti-adhesion performance of emitters showed that the SS-Ⅱ emitter had the best comprehensive properties. The method provides reference for the structure design of high performance emitters.

Key Words: Particle-wall mechanical model, Adhesion, Visualized

Measurements of Laser-induced Plasma Temperature Field in Deep Penetration Laser Welding

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Abstract: Laser welding is a highly automated process that is progressively more and more employed in the automotive industry. Laser-induced plasma, which appears during laser welding, plays a significant role in interactions between the laser energy and materials. Plasma in deep penetration laser welding comprises plasma plume and keyhole plasma, which locates outside and inside the keyhole, respectively. The characterization of plasma can be described in terms of electron temperature, electron density and absorption coefficient. Generally, electron temperature and electron density are employed to describe the plasma behavior. Much research has been devoted to spectroscopic measurements of plasma. However, little research has been done to obtain the electron temperature distribution of the plasma plume or the keyhole plasma on a certain horizontal plane. Spectroscopic measurements upon a wide range of the plasma emission (including ultraviolet, visible and near infrared) contain information on plasma characteristics such as its composition, electron temperature, electron density, and absorption coefficient. In this paper, the temperature field of the plasma plume and the keyhole plasma are studied by plasma emission spectroscopy. The spectroscopic measurements of plasma under deep penetration laser welding conditions are carried out with a high power continuous wave (CW) CO_2 laser with output power up to 2500 W. Argon gas from a coaxially planed nozzle, 8 mm in diameter, was used as shielding gas. The workpiece is put on a worktable which is controlled by a CNC program. In terms of the keyhole plasma, a 'sandwich' sample referring to the method adopted by Zhang et al. is introduced in this work. Specially, an iron film is clamped between two pieces of GG17 glass in the 'sandwich' sample, so the emission light of the keyhole plasma can be observed by collimator through the glass. The metal film used here is SUS304 with thickness of 0.2 mm. In both cases, the plasma radiation is observed by a quartz collimator and guided to a spectrometer by a plastic optic fiber of 200 μm diameter. For the sake of receiving spectra from several points separately and simultaneously, an Optical Multi-channel Analyser (OMA) based on our special designed 'multi-channel fiber', is developed to take the spectra of the plasma plume and the keyhole plasma. During our experimentations, a spectral band is chosen between 379 nm and 420 nm, since the charge coupled device (CCD) has its best response and useful lines could be found easily in this spectral band. On the assumption that the plasma is in local thermal equilibrium (LTE), the electron temperatures are calculated with the 'Boltzmann plot' method. The spectra collected by the spectrometer are processed with a modified inverse Abel transform for the asymmetry emission source. Hence, the electron temperature distribution of the plasma plume and the keyhole plasma is figured out. Experimental results show that microscopic parameters of the plasma plume and the keyhole plasma are not unique. For our welding conditions, the maximum electron temperature reaches 8467 K for the plasma plume and 17931 K for the keyhole plasma. The electron temperature fields of the plasma plume and the keyhole plasma are both almost cylindrically symmetrical and the temperatures are higher in the centre than that around. The results of this study may be of interest to well understanding of negative lens effects of laser-induced plasma during laser welding.

Keywords: Laser Welding, Plasma Plume, Keyhole Plasma, Abel Inversion

Experimental and Simulation Analysis on Particle-Wall Adhesion in Rectangular Emitter Channel

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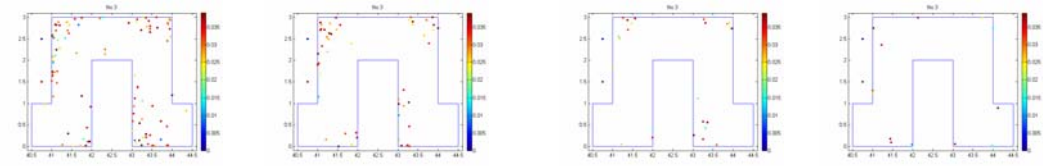
Abstract: Clogging in emitter micro-channel is the biggest problem hindering the development of micro-irrigation. Particle-wall adhesion is one of the important reasons leading to emitter clogging. In this paper, the viscosity of the sand is taken into consideration. And the adhesion model, which is proposed under energy equilibrium（the kinetic energy equals to the interface free energy）, $E_k = E_S$, is given out from the micro-perspective. And the critical criteria for evaluating the occurrence of particle-wall adhesion is given, $u_{\mathrm{cr}} = u_{\mathrm{p}} = \sqrt{\frac{2\pi\gamma(6\pi\gamma R^2)^{2/3}}{m_{\mathrm{p}}K^{2/3}}}$. Adhesion takes place when the relative velocity between the particle and the wall is less than the critical velocity u_{cr} PIV (Particle Image Velocimetry) visualized experiments are carried out under these conditions: 10kPa as the emitter's inlet-pressure, with the same particle concentration and the same particle distribution. The experimental results are shown in Fig.1, which are recorded under the same experimental time and with the same channel-unit, but under various inlet-pressures. Based on the particle-wall adhesion model, numerical simulation is performed with the software FLUENT. The user defined function is used here to take the adhesion model into consideration. And the software MATLAB also used to post-treatment the data of the simulation results. Here, a concept, adhesion ratio, is proposed. It is defined as the ratio of the total number of the adhered particles to the total number of the injected particles. Firstly, the effect of the inlet-pressure on particle-wall adhesion and the starting position of adhesion occurring are analyzed. And the analyzed results are shown in Fig.2. From Fig.1 and Fig.2, that's easy to give out these similar conclusions: (1) The inlet-pressure has a great effect on the particle-wall adhesion and the lower the inlet-pressure is, the easier the particle-wall adhesion will take place; (2) The particle's adhesion in emitter first occurs on the outer turning of the channel-unit, and the particle adhesion on upstream faces is heavier than on the other positions. Furthermore, the adaptability of the adhesion model is verified by the same conclusions given by the experimental results and the simulation results. For further study, then the effect of the surface energy and particle diameter, the effect of the channel-unit's position on particle-wall adhesion and the distribution of the adhered particles are analyzed under the conditions have been mentioned above. And conclusions, as follows, can be reached: (1) The larger the surface energy of the particle-wall interfaces is, the easier the particle-wall adhesion will take place. (2) The smaller the particle diameter, the easier the particle-wall adhesion will take place. Thus, researching on the surface energy and the particle distribution are necessary for evaluating the emitter clogging; (3) To the smaller particles, most of them will adhere to the wall in the front of the emitter, while to the larger particles, the adhered tendency become even in the whole channel,. This means, the emitter clogging is easier to take place in the front of the emitter; (4) From the statistical data under the simulation results, the adhered particles distributed on the anterior and posterior walls are no more than 32% of the tatal adhered particles. It means that particle-wall adhesion occurs easier on the other inner walls than the anterior and posterior walls.

10kPa 30kPa 50kPa 70kPa

Figure 1 Adhesion results under different inlet-pressure



10kPa 30kPa 50kPa 70kPa

Figure 2 The distribution of the adhesion particles

Keywords: Adhesion model; Critical velocity; PIV visual experiment; Mathematical simulation.

Fabrication of three-dimensional electromagnetic band-gap structure with alumina based on stereolithography and gelcasting system and its performance study

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Abstract: Three-dimensional (3D) diamond structure electromagnetic band-gap (EBG) structures made from alumina-slurry dielectric composites which contain 55vol% Al_2O_3 powder were fabricated by means of stereolithography (SL) and gelcasting system. The lattice constant was 12mm, the band-gap in the <110> direction measured appeared at 9.00-12.00GHz, which agreed fairly well with the band-gap simulated based on finite element method (FEM) in Ansoft HFSS software. In addition, the samples of EBG structure of alumina-resin (before sintering) and that of alumina-air (after sintering) were tested and investigated in accordance with the changes of dielectric constant of the structures before and after sintering.

Key words: EBG, band-gap, SL, gelcasting, photonic crystal

Micro-void Coalescence Model and Ductile Fracture Criterion in Metal Forming Processes

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Abstract: Ductile fracture in metal forming process is the cumulative result of damage, and usually follows a multi-step failure process involving nucleation of microscopic voids, growth of voids, localization of plastic flow and coalescence of voids. A void coalescence model based on a three-dimensional unit cell is proposed in this paper to establish the relationship between the critical strain to fracture ε_f and the void volume fraction f .

$$\varepsilon_f = \ln\left\{\frac{1}{4\left(2-\sqrt[3]{f^2}\right)}\left[2\sqrt{\frac{1}{3}}\left(1-\sqrt[3]{f}\right)\left[\left(2+\sqrt{5}\right)+\sqrt[3]{f}\left(\left(3+\frac{1}{\sqrt[3]{f^4}}\right)^{\frac{1}{2}}+\left(3+\frac{2}{\sqrt[3]{f^4}}\right)^{\frac{1}{2}}\right)\right]+\frac{2\left(\sqrt{2}+1\right)}{\sqrt{3}}\left(\frac{2}{3}\frac{1}{\sqrt[3]{f}}-1+\frac{1}{3}\sqrt[3]{f^2}\right)\right]\right\} \tag{1}$$

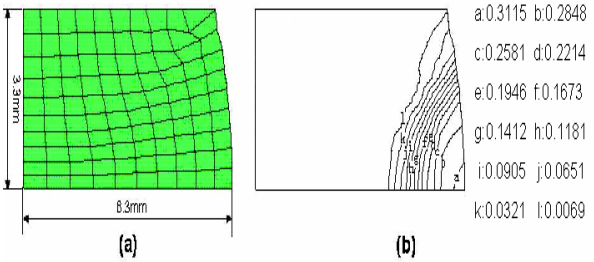
Void volume fraction in fracture area of specimens in uniaxial tension experiment is measured, and it is confirmed that the relationship between the critical strain to fracture and the void volume fraction, calculated by using the proposed model, agrees better with the experimental results than that calculated by two-dimensional model.

From metallographic observation, the mechanisms of ductile fracture could be divided into two modes: tension-type and shear-type. Tension-type mode attributes ductile fracture to the prevailing tension state with obviously increasing void volume fraction, moreover, voids elongate in one dimension along with strain increasing. A typical deformation process belonging to this mode is uniaxial tension, On the other hand, shear-type mode attributes ductile fracture to the prevailing shear state with obvious elongation of the voids along the direction of shear bonds, a typical deformation process is torsion. A unified fracture criterion for predicting ductile fracture is proposed, which could be applied for both fracture modes:

$$\int_0^{\bar{\varepsilon}_f}\left(\frac{\sigma_1}{\sigma_1-\sigma_m}+C_1\frac{\sigma_1}{\sigma_1-\sigma_3}\frac{\sigma_3'}{\sigma_1'}\right)d\bar{\varepsilon}_p = C \tag{2}$$

here $\bar{\varepsilon}_f$ is the critical effective plastic strain at fracture; C_1 and C are material constants under general deformation conditions. The two integration items in the left of Equation (2) denote the influence of the increase of voids volume fraction and elongation of voids shape on damage evolution, respectively. Item $\sigma_1/(\sigma_1-\sigma_m)$ denotes that larger maximal principal stress σ_1 and hydrostatic stress σ_m induce more increase of voids volume fraction, accelerate the accumulation of tension-type damage. Item σ_3'/σ_1', is used to represent the influence of stress deviator σ_{ij}' on the shape of voids. While item $\sigma_1/(\sigma_1-\sigma_3)$, denotes the relative magnitude of the effect of tension and shear under general deformation condition. When the integration of the left of Equation (2) approaches C, the material arrives at the critical state of ductile fracture.

User defined subroutine VUMAT in program ABAQUS is developed to introduce the proposed ductile fracture model, and simulations of various deformation processes are performed. Experiments of uniaxial tension, torsion and upsetting are carried out. Material constants C_1 and C, calculated by using experimental results of tension (notched R2.5) and torsion, is used to predict the occurrence of ductile fracture for the upsetting specimen HD1:1. Predicted results shown in Fig.1 agree well with experimental results. The comparison of numerical results and experimental results validates the accuracy and wide applicability of the proposed fracture criteria. The proposed criteria is also applied to predict ductile fracture to some metal forming processes, such as forward extrusion and deep drawing, the predictions show good agreement with experimental results.



(a) Deformed mesh; (b) Distribution of the damage value
Figure 1 Numerical results for specimen HD1:1 at fracture

Keywords: Micro-void coalescence, ductile fracture

Analysis on Elasto-plastic Stability and Propagation of Buckles for Lifting Pipeline

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Abstract: According to design requirements of deep-sea mining lifting system, elasto-plastic stability and propagation of buckles for lifting pipeline were systematically analyzed under together action of the external pressure and bending. The relationships among the initial buckling pressure of pipeline, propagation pressure and wall thickness were studied. Taking into account of the initial non-roundness of the pipe and material submitted under the nonlinear case, calculation methods of the critical buckling load and propagation pressure were optimized.

Key Words: lifting pipe; elasto-plastic stability; buckling spread

Vibration and Damping Characteristics of Cylindrical Shells with Active Constrained Layer Damping Treatments

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Abstract: In this paper, the application of Active Constrained Layer Damping(ACLD) treatments is extended to the vibration control of cylindrical shells. The governing equation of motion of cylindrical shells partially treated with ACLD treatments is derived on the basis of the constitutive equations of elastic, piezoelectric, visco-elastic materials and energy approach. The damping of visco-elastic layer is modeled by the complex modulus formula. A

finite element model is developed to describe and predict the vibration characteristics of cylindrical shells with partially treated with ACLD treatments. A close-loop control system based on displacement and velocity feedback is considered. The dynamic behaviors of cylindrical shells with ACLD treatments such as nature frequencies, loss factors and responses in frequency domain are further investigated. The effects of several key parameters such as control gains, location and coverage of ACLD treatment on vibration suppression of cylindrical shells with ACLD treatment is also discussed. The numerical results indicate the validity of the finite element model and the control strategy approach. The potential of ACLD treatments in controlling vibration and sound radiation of cylindrical shells as the major critical structures such as cabins of aircrafts, hulls of submarines and bodies of rockets and missiles is thus demonstrated.

Key words: Cylindrical shell, Piezoelectric; Viscoelastic

Chaotifing Duffing-type System with Large Parameter Range Based on Optimal Time-Delay Feedbacks

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Abstract: This report presents a technique of chaotification based on the optimal time-delay feedback that can make a system chaotic with large chaotic parameters range. An implicit performance-index function and optimization strategy are proposed for the time-delay control scheme that can be effectively carried out to obtain the best delay time for chaos with best quality. The performance-index (i.e. objective function) is constructed based on the frequency spectrum obtained by Fast Fourier Transform (FFT), which is a simple and applicable index to represent chaotic performance. With respect to delay time, the objective function is non-derivative, leading to losing effectiveness of the gradient-based optimization method. Moreover, the index is sensitive to the

delay time, and there exists many local minima. The global optimization methods, such as Genetic Algorithm (GA), may be suitable, but they are computationally expensive. As a result, a direct search method with proper initial guess and step size, i.e. Hooke & Jeeves' method, is adopted. Simulation results of Duffing-type systems show that it is possible to excite the system behaving chaotically while the feedback controls remain small at favorable level. Chaotification performance is further discussed when the excitation frequency is widely changed. Results also reveal an interesting phenomenon that the optimal time-delay chaotification can reduce or even eliminates line spectra apparently when the excitation frequency is lower than a characteristic frequency (about 8 Hz), which may potentially lead to an application for line spectra reduction of the radiated noise emitted from underwater vehicles. The parametric studies on excitation frequency and feedback gain are also carried out, which indicates that it is easier to chaotify the system excited by the harmonic force with the higher frequency than that with lower excitation frequency, and the larger feedback gain is used, the higher quality of chaotification is delivered. However, the large feedback input will induce the vibration with large amplitude and enhance the maximum amplitude of frequency spectrum, when the excitation frequency is higher than the characteristic frequency (about 8 Hz). This is an unexpected phenomenon that will be harmful for design of vibration isolator. Consequently, our further work in future will focus on improvement of chaotic performance to reduce line spectra in the nonlinear vibration isolator system for any excitation frequencies, and theoretical study on the optimal time-delay chaotification.

Keywords: chaotification, time-delay feedback, line spectrum, design optimization

Feasibility of Vibration Control Based on Piezoelectric Actuator and Ultrasonic Sensor

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Abstract: Vibration control is an important branch of vibration engineering area, which is applied widely in aerospace field, civil engineering, vehicle structure and so on, and has aroused wide attention of scholars. In traditional method of vibration control, sensor is pasted in measure point and actuator is installed in the controlled object. Then signal acquisition and control modules are connected by the wire. Recently, non-contact vibration control research is a hotspot, such as wireless mode, optical sense and machine vision. Ultrasonic have the advantages of good direction, high precision and non-contect with the tested object, thus it is a good method to detect the vibration signal. Piezoelectric ceramic has the advantages of small size, light quality, the small additional quality for base structure, and has a widely application as actuator in all kinds of vibration control based on intelligent structures. So this paper presents a vibration control method for the piezoelectric cantilever beam used extensively, based on the ultrasonic sensor and the piezoelectric actuator.

Although ultrasonic ranging techniques are very often used to measure distances, they have not been applied to the measurement of vibration signal in vibration control field as described here. In this system, using the piezoelectric cantilever beam as the vibration control object, the ultrasonic sensors which contain one transmitter and one receiver are used to detect the variation of transmitted time and phase angle when the cantilever beam is shaking. And the variation of vibration displacement which is the vibration signal of cantilever beam can be obtained. The detection signal is amplified by charge amplifier and filtered by low-pass filter, and accessed to industrial computer which contain A/D converter, PID control algorithm, D/A converter. Finally, it is feedbacked to piezoelectric actuator drived by electrostrictive ceramic micropositioner. Piezoelectric actuator generates torque to restrain the vibration of the cantileve beam through the variation of feedback.

Firstly, the models of cantilever beam, ultrasonic sensor and piezoelectric actuator are established. The beam is assumed to be a intelligent piezoelectric cantilever beam. Take the element of composite piezoelectric beam as an example to discuss, and suppose the upper layer as actuating layer and the lower layer as sensing layer. Each node has four degrees of freedom, deflection, rotational degree of freedom and two electric potential degrees of freedom. Combined to the piezoelectric equation, the displacement of composite piezoelectric beam unit gets the same displacement form as the standard finite element, and the piezoelectric layer and sub-structure are assumed as the same displacement mode. The electric field to piezoelectric beam element is the main consideration, and the upper surface for actuation and the lower surface for the sensor to the beam are supposed. When equal potential is assumed among the node and every point, the motion equation about the whole structure of piezoelectric beam can be obtained according to the calculation of assumed motion equations.

The detection system contains two ultrasonic transducers, one transmitter and one receiver. The ultrasonic is transmitted by the transmitter, and reflected back when meeting the cantilever Beam, then received by the receiver. There is a phase difference between the transmitting and receiving waveforms. The vibration displacement is related to the phase difference.

According to converse piezoelectric effect, due to the polarization direction of piezoelectric actuator is the Z direction, the piezoelectric elements will produce tension and compression in X direction. Piezoelectric actuator bonded on the beam under voltage will generate bending moment function in surface of cantilever beam. The control torque of piezoelectric actuator is only proportional to the control voltage.

Then, the PID controller structure of cantilever beam is established. The vibration displacement on the cantilever beam detected by the ultrasonic sensor is considered as the control feedback quantity. The deviation can be obtained according to the given displacement value and practical output, which is used as the input of the PID controller. The control variable which is the output of the PID controller is proportional, integral and derivative linear combination of the deviation. Based on the converse piezoelectric effect, the piezoelectric actuator generates the driving torque on the cantilever beam after inputting the control variable, which inhibits the elastic vibration of cantilever beam.

Finally, Based on the model of cantilever beam, ultrasonic sensor and piezoelectric actuator, the cantilever beam control system is built by Matlab/Simulink software which is controlled by PID controller. Using Ziegler-Nichols setting method to adjust PID parameters, two group ideal vibration parameters are obtained. Operated simulation model, the vibration displacement curves of cantilever beam are gained when the inputs are a pulse force and a harmonic force. Compared two group vibration curves which have PID controller or without PID controller, the vibration situation is analyzed. The simulation results show that the new method is feasible and the system performance is improved when using the ultrasonic sensor to detect vibration displacement signal and adopting piezoelectric element to generate driving torque.

This paper proposes a new idea for vibration control research. However, the vibration velocity or the displacement is obtained through computer system which calculates and analyzes the ultrasonic detecting signal in this method. The measurment performance and frequency response of ultrasonic sensor and time delay of the system should be taken into consideration in the actual system. So the control system still needs to be experimented furtherly.

Keywords: Ultrasonic sensor, Piezoelectric actuator, Non-contact, Vibration control

Dynamic Simulation and Analysis of axial piston hydraulic motor pump

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abstract

A new type of axial piston motor pump model is established, and its principle of operation has been analyzed. By using the Dynamic Simulation Mechanism in Pro/E Software to make the dynamic analysis of the mathematical model, we can obtain axial piston motor pump kinematic parameters to support the design.

Key words: Hydraulic motor pump, Working principle, Pro/E Mechanism, Dynamic analysis

Research on Numerical Simulation of Three-Screw Pump Flow

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Abstract：A kind of small-volume, high-pressure difference and new energy-saving line-modified three-screw pump was proposed. Based on the limited volume method, the numerical simulation model of this pump was established. By analyzing its basic rules such as velocity field, pressure field and the three-screw pump flow channel's volumetric efficiency is obtained. The research indicated that the flow channel pressure progressively increased along with the sealed chamber; the eddy flow phenomenon existed in the flow channel spiral flute, the negative axial velocity existed in the contact area of rotor and pump cover's wall surface and the meshing area, which were the main leakage areas; the volumetric efficiency of line-modified three-screw pump increases as the rotate speed increases and reduces the transferred liquid when viscosity increases. The research findings will provide theory basis for screw pump's development design in the future.

Key words: three-screw pump；line；modify；flow field；numerical simulation；eddy flow

Improved Reliability Index Approach and Performance Measure Approach for Reliability Assessment of Probability Constraint Based on the First Order Reliability Method

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Abstract:

Reliability Index Approach (RIA) and Performance Measure Approach (PMA) have been used widely for reliability assessment of probability constraint in the Reliability Based Design Optimization (RBDO). On the condition of accepting approximate accuracy of the First Order Reliability Method (FORM), the existing RIA and PMA are studied in this paper including their limitations when the failure event is defined as the value of performance function is less than zero. The improved RIA and PMA are proposed to respectively overcome the relevant limitation based on the FORM. Examples are used to illustrate the validities of the proposed methods. The limitations of the proposed methods are also analyzed.

To judge the feasibility of a probability constraint, RIA directly calculates the probability of failure of a performance function. In the method of RIA, after transforming all random variables and parameters in the X-space into standard normal ones in standard normal space (U-space), the reliability index is defined as the minimum distance from the original to the limit state function (G(**U**)=0), and this point on the limit state function is called Most Probability Point (MPP). From examples, same reliability indexes can be obtained for performance functions as G(**U**)=0 and –G(**U**)=0, thus same probabilities of failure will be obtained. However, the probabilities of failure for G(**U**) and –G(**U**) are different. From theoretical deduction, the existing RIA has trouble when the MPP is collinear and has the same direction with the gradient of performance function at the MPP. Thus, the improved reliability index approach is proposed to overcome this limitation: from theoretical deduction, the reliability index is the minus vector product of the MPP with the unit gradient of performance function at MPP. Then the probability of failure can be obtained using this reliability index. From results of the same test examples, the improved reliability index approach obtains the true results, and overcomes the limitation of the original RIA.

To judge the feasibility of a probability constraint, PMA evaluates the value of a performance function when the probability of failure equals to the predefined one. In the method of PMA, after transforming all random variables and parameters in X-space into standard normal ones in U-space, the first order probabilistic performance measure is the minimum value of performance function in U-space on the target reliability index hyper-sphere, and the corresponding point is also called MPP. From example, when the values of performance function in the U-space at the points on the target reliability index sphere surface are all not less than zeros while the values at the points in the sphere are less than zeros, the existing PMA will have trouble in judging the satisfaction of the probability constraint. To overcome this limitation, the improve performance measure approach is proposed: both cases of gradient of performance function at the MPP unequal and equal to zero are discussed, from theoretical deduction,

the performance measure is the value of performance function in and on the target reliability index sphere. From the results of the same test example, the improved performance measure approach obtains the true result, and overcomes the limitation of the original PMA.

The limitations of the improved reliability index approach and improved performance measure approach are also discussed. Because all theoretical deductions are based on the FORM, hence these two methods have all limitations of the FORM. Because in FORM, the performance function is approximated with the first order Taylor expansion at the MPP. For nonlinear performance function in the U-space, the FORM, and also the improved reliability index approach, will overrate and underrate the probability of failure for non-convex and convex function, respectively. When the limit state function is a cycle or hyper-sphere surface in U-space, the largest error will be caused by FORM. The confidence is the integration of joint probability distribution in U-space with integral region as in and on the reliability index sphere when the probability constraint is satisfied judging by the improve reliability index approach and improved performance measure approach.

Keywords: Improved Reliability Index Approach, Improved Performance Measure Approach, Reliability Based Design Optimization

An approach to high-frequency excitation of electrohydraulic vibrator

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Abstract: An excitation means of electrohydraulic vibrator is proposed and aimed to enhance the working frequency. The vibrator is a symmetrical hydraulic cylinder controlled by a 2D valve, in which both rotary and linear motions of a single spool are used to vary the frequency and the amplitude independently. The frequency of the vibrator is proportional to the rotary speed of the spool and thus the high-frequency is achieved by increasing the rotary speed of the spool well lubricated in hydraulic oil. In 2D valve, the rotary motion of the spool coordinates the grooves of the spool land with the windows on the sleeve and alternates flow into and out of the chambers of the hydraulic cylinder, thus exciting the piston (rotor) to output a vibration. The spool's linear motion is used to adjust the peak flow rate and thus the amplitude of the output vibration. The rotary motion of the spool is driven with a variable AC servo motor while the linear motion of the spool is actuated and positioned the same way of the direct actuated digital valve. In this way, the frequency and the amplitude of the vibration wave output from the cylinder are varied independently via the two independent input signals to the 2D valve controller. The frequency range of the vibrator is to a large degree constrained by the rotary speed of the spool of the 2D valve. The rotation of the AC servo motion is transmitted to the axis of the spool through a gear chain with an effective speed amplification of four. The actual frequency range for the experimental system was 0~800Hz.Experiments have been carried out to the vibrator loaded by an elastic force coming from the deformation of a frame work and the wave forms of the cylinder piston was measured. It is demonstrated show that the ascent and descent slopes of the wave form show some inconsistency which alleviates with the reduction of valve linear opening. The phenomenon is explained to be caused by the changing direction of the elastic force. Nevertheless, the wave from is close to a sinusoidal one. It is concluded the proposed method does point out an approach to the high-frequency excitation of the hydraulic vibrator.

Keywords: High frequency, 2D valve, vibrator, Electrohydraulic

The conjugated profile of roller chain in timing mechanism of engine

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Abstract: Roller chain drive is recognized to be one of the most effective forms of power transmission in mechanical systems. It has a basic feature with a constant ratio because of no slippage or creep. Roller chain drive is widely used in timing mechanism of gasoline engine. However, its polygonal action and the meshing impact effect resulted from the non-conjugated meshing feature may damage the synchronization and uniformity of transmission.

In this paper, new sprocket tooth profile is developed to reduce polygonal action and meshing impact under high speed. The new involute conjugated profile is derived to guarantee that the moving distance of chain is equal to the arc length of pitch circle that sprocket rotates at the same time and the centre line of chain at tight side is tangent to the pitch circle always. An asymmetrical modification method for the sprocket tooth profile is also proposed. The multi-body dynamic model of timing mechanism in engine with the intake and exhaust sprockets is developed. The fluctuation and meshing impact of chain are analyzed under different rotational speeds.

The multi-body dynamic model of timing mechanism with intake and exhaust sprockets in engine is established and simulated. The meshing impact effect between chain link and sprocket, the friction between chain link and transmission components, the tension force and the fluctuation of chain can be obtained. The results show that new developed sprocket profile can efficiently reduce the dynamic effect and meshing impact of chain drive. The obtained involute sprocket tooth profile can guarantee that the rollers mesh into sprocket gradually. Thus, the impact force between roller and sprocket can be greatly decreased. The stability of chain transmission under high speed can be improved.

Keywords: Roller chain drive; Timing mechanism; Modification; Sprocket

Lead Port-based Ontology to Concept Generation by Using Incidence Matrix

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Abstract: The country is currently facing serious economic challenges, and enterprise is no difference. Global competition has forced enterprises to seek new strategies for increasing market shares. One strategy often utilized by enterprises is to increase the supply of product varieties to the market with the intention that almost every customer may find a product that meets their preferences. It is the fundamental strategies for an enterprise which relies on new product for survival and development. However, as the description of design requirements at early stage is inaccurate and vague, it is difficult to customize product schemes. It will play an important role for product development in the preliminary design stage. Meanwhile, port is crucial to capture component concept and realize conceptual design for multi-solution generation. In this paper, the related work of several matrix modeling is introduced. An incidence matrix based on port ontology is built to support for product conceptual design. Its aim is to implement modeling of design process to guide multi-solution generation. It can be formally employed to represent and organize product information in both functional ontology and physical domain in a hierarchy. The taxonomies and attributes are represented by analyzing port-based domain knowledge. Port compatibilities are used to match and link two components. This makes them possible to construct an incidence matrix which can be decomposed into an independence matrix, and allow designers from different backgrounds with various interests to access the design ontology. The coded rules of matrix elements are described and stand for port attributes of the components. The process of the multilevel matrix modeling is constructed to generate principle schemes of products at different levels of abstraction, which facilitates design decision-making towards the whole stage of conceptual design. Finally, an empirical study is given to describe the process of incidence matrix transformation and demonstrate the proposed approach.

Keywords: Port-based ontology, Compatibility, Taxonomy, Incidence matrix, Conceptual design

Novel Chemically Treated Bioactive Surgical Fixation Devices for ACL Reconstruction

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Abstract: Around 400,000 anterior cruciate ligament (ACL) reconstructive surgeries are performed every year worldwide. In order to overcome the shortages of current existing surgical fixation devices, a new technique-chemically generated bio-reagent storage surface on biopolymer device which can assist in bioactive materials delivery has explored. As a unique feature, the device was treated using an innovative chemical surface etching method which creates textured surfaces with embedded micro reservoir structures for bio-reagents. The bioactive reagents of the device will provide osteoinductivity and osteoconductivity, which promotes bone growth and bonding to the surrounding normal bone without intervening fibrous tissue. Stable initial fixation will be obtained by direct binding to the surrounding bone through the effects of embedded bioactive reagents. Combining surface bio-reagent storage and good initial fixation, the chemical treated surgical pin provides the feasibility to create a new generation of surgical fixation tools.

Keywords: Surgical Fixation Devices, Chemical Treatment, Bioactive

A Real-time Algorithm for Convex Hull Construction and Delaunay Triangulation of Scattered Points Data

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Abstract: Convex hull, as a basic data structure of computational geometry design, plays an important role. This paper presents an algorithm to construct the convex hull of a set of scattered points by coordinates and relative angle method. The algorithm can determine the convex vertexes and at the same time can eliminate some non-convex vertexes, which greatly reduces the searching scope and the complexity. Delaunay triangulation is widely applied in 3D surface reconstruction. Because of the duality, Delaunay triangulation is usually constructed through Voronoi diagram. Delaunay triangulation is directly constructed in this paper. The algorithm is simple, stable and easy to be realized, especially suitable for less data points.

Keywords: computation geometry, scattered points, convex hull, Delaunay triangulation

Adaptable Design for Creating Changeable Products to Satisfy Changeable Requirements

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Abstract:With the advances of design and manufacturing technologies, more products with good quality and low costs are produced to satisfy the requirements of customers. The advances of these technologies, however, result in excessive wastes at the ends of the life-cycles of these products. To solve this problem, a new design approach, called adaptable design, was introduced to create a single adaptable product to replace the multiple products. Different from the traditional products whose functions are maintained through services and repairs, functions of the adaptable products can be improved or changed through adaptation activities such as upgrading and reconfiguration.

Many methodologies and applications have been developed so far for adaptable design. Despite the progress, the presently developed adaptable design methods primarily focus on improvement of product structures to reduce the effort of adaptation tasks. Since the objective of adaptable design is to create a product that can be adapted in different time periods of its life-cycle, study on the creation of an adaptable product considering the changes of design requirements in the whole product life-cycle is needed.

In this research, a method to identify the adaptable product based on changeable requirements is introduced. The optimal adaptable design model considering changes of design requirements, configurations and parameters in the whole product life-cycle is shown in Fig. 1. In this method, the changeable requirements are defined as functions of a newly introduced life-cycle time parameter T. The adaptable product, modeled by its configurations and parameters, is also changed in different life-cycle time periods to satisfy these different requirements. Among the feasible solutions, optimization is employed to identify the optimal adaptable product based on the evaluation to the design candidates considering the whole product life-cycle span. Case study has also been conducted to demonstrate the effectiveness of the introduced optimal adaptable design method.

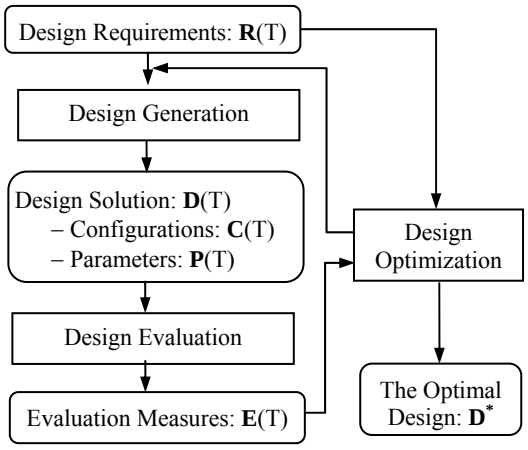

Figure 1 The optimal adaptable design model

Advantages of this optimal adaptable design method are summarized as follows:

- By sharing the modules in different configurations of the adaptable product for satisfying different requirements, the adaptable design method can reduce the wastes created at the end of the product life-cycle.

- Instead of identifying the optimal design based on the evaluation at the time of product purchase, the optimal adaptable design method can identify the optimal design considering the whole product life-cycle span.

Keywords: Adaptable design, Product life-cycle, Optimization

A NOVEL COUPLED AND SELF-ADAPTIVE UNDER-ACTUATED MULTI-FINGERED HAND WITH GEAR-RACK-SLIDER MECHANISM

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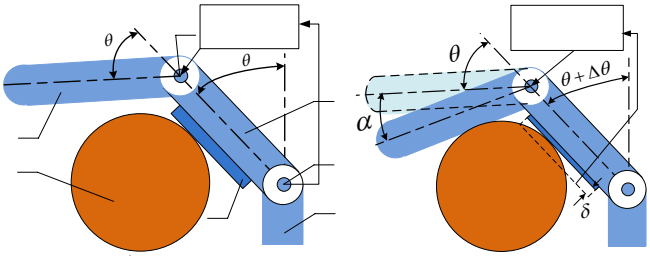
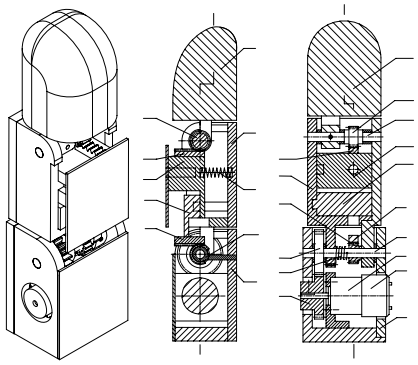
Abstract:
Aiming to overcome the serious disadvantages of two kinds of under-actuated fingers: coupled finger and self-adaptive finger, this paper proposed a novel grasping mode, called Coupled and Self-Adaptive (COSA) grasping mode, which includes 2 stages: firstly coupled and then self-adaptive grasping, shown in Figure 1.

A 2-joint COSA finger with double gear-rack-slider mechanisms (called COSA-GRS finger), is designed based on the COSA grasping mode, shown in Figure 2: at beginning, the 2-joint finger bends with coupled mode, two joints of the finger rotate simultaneously with a fixed ratio until the proximal phalanx touches the grasped object, then the finger will automatically decouple and rotate with self-adaptive mode, the distal phalanx quickly rotates until it touches the object.

The new finger unit has the advantages of coupled finger and self-adaptive fingers. The finger is not only able to rotate all joints simultaneously to pre-shape before grasping objects, but also is able to self-adapt different sizes and shapes of objects. Using the same mechanism as the 2-joint finger, a 3-joint COSA finger is designed.



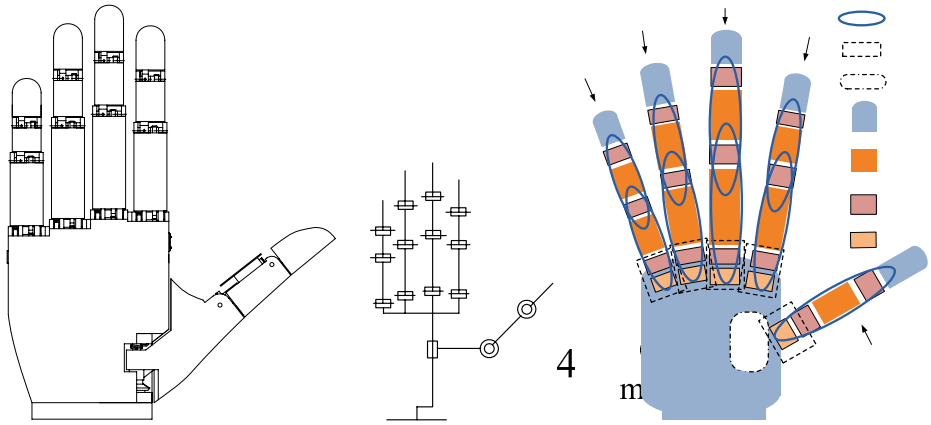
(a) 1st stage: coupling (b) 2nd stage: self-adaptation
1-base; 2-proximal joint; 3-proximal phalanx; 4-distal joint;
5-distal phalanx; 6-receiver (movable slider); 7-the grasped object
Figure 1 Two stages of COSA grasping mode



(a) (b) (d)
Figure 2 Mechanical design of 2 joints COSA-GRS finger

Force analyses and structure optimization rule of the new finger are given and discussed. The simulation results show that the finger unit is effective: it can successfully realize coupling and decoupling and it can stably grasp objects.

An under-actuated humanoid robot hand is developed, called the COSA-GRS Hand, shown in Figure 3. The hand has 5 fingers, 15 joints and 6 motors. All fingers of the hand are COSA fingers. The hand is more similar to human hand in appearance and actions, able to more dexterously and stably grasp different objects than tradition coupled or self-adaptive under-actuated hands.



(a) Front view (appearance) (b) DOFs of the hand (c) Modules of COSA-GRS Hand
1-palm; 2-thumb; 3-index; 4-middle finger; 5-ring finger; 6-little finger; B-base; J-joint
Figure 3 The COSA-GRS Hand

Keywords: Multi-fingered hands, Under-actuated finger, Coupled finger, Self-adaptive finger, Grasping mechanism

Kinematic Analysis of a Hybrid Manipulator for Damping System of Vehicular Devices

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Abstract: In this paper we present a hybrid manipulator for the damping system of vehicular devices. The manipulator combines a 3PUU translational manipulator and a 3UPS/(P)U redundant manipulator in series. In order to isolate multi-dimensional vibrations with this manipulator, spring-damper subsystem is introduced to this system. Since the damping system includes passive damper and magneto-rheological damper in the two sub-manipulators, it can isolate the disturbances with low and high frequencies. The hybrid manipulator is described detailed and the coordinates system is assigned firstly, then the inverse kinematics matrix is derived analytically. The linear velocity and angular velocity are decoupled completely, so the Jacobian matrix can be easily derived according to the Jacobian matrices of the sub-manipulators, which are solved by the loop equations method. Furthermore, the distribution of workspace is generated with Matlab in view of the physical constraints imposed by mechanical joints and actuators. Dexterity is an important kinematic performance index, which can be regarded as the ability of the manipulator that can arbitrarily change its positions and orientations. The condition number of the Jacobian matrix is used as the index of dexterity in this paper. In order to avoid the inconsistency of the index, the Jacobian matrix is separated into translational Jacobian matrix and rotational Jacobian matrix, and the distributions of their condition number are given. At last, the distributions of maximum and minimum stiffness are derived by the method of screw theory. All these performance indices show that this hybrid manipulator is a feasible candidate for the damping system. The research works provide an analytical base for the development of the damping system with parallel manipulator of vehicular devices.

Keywords: Damping system, hybrid manipulator, vehicular devices

Predictive Tracking and Feedforward Compensation of Seams by Industrial Robots for High Speed Laser Welding

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Abstract: In this paper, a novel architecture for robotic seam tracking using industrial robots and off-the-shelf sensors is proposed to compensate residual errors in nonlinear tracking and bursting-type shifts of robot path which become notable for high speed robotic laser welding in most industrial environments.

In the past decades, great research effort has been made on robotic line/path following with high precision. However, only a small portion of research involves high precision tracking at high speed. There are also notable differences when comparing research focuses from the industrial section and the academic section. Therefore it is beneficial to investigate possible conjunctions of existing approaches and propose a flexible architecture which can utilize existing achievements from both industrial sections and academic sections.

The architecture of robotic seam tracking methods is generally dependent on the sensors used to detect seam positions. Two typical kinds of vision sensors widely used in robotic seam tracking are TCP co-axial sensors and 3D profile sensors based on triangle principle. The TCP co-axial sensors are normally used to obtain the offset errors between Robot TCP and the seam to be followed, and in some cases they can also sense the seam in front of the TCP. However the performances of such sensors are subjective to various image noises arising during a robotic welding process. Moreover a slow image processing speed also largely constrained the usage of such sensors for high speed tracking. In contrast, 3D profile sensors are faster, more precise, and more robust, and are usually installed at a look-ahead distance away from the TCP of robot. Such sensors typically have a single laser stripe, and can only provide limited look-ahead information. Most recently, some robot tracking system with a multi-line laser sensor have been demonstrated. In principle, it is possible to estimate the TCP offset error by extrapolate information of multiple laser stripes, and hence combine the benefits of the above two types of sensors. Nevertheless, such sensors are not off-the-shelf sensors and the reported average tracking precision is still not adequate for autonomous laser welding.

Depending on how much information can be extracted from tracking sensors and how to translate the information to robot control commands, we classify typical seam position prediction schemes into incremental pose prediction and absolute pose prediction. When be enhanced with other techniques, such as feedback control, feedforward compensation, or intelligent control methods, these schemes can lead to more advanced and complicated tracking methods. The readers may find different classification where seam tracking methods are classified as visual servoing and trajectory-based control. However our classification leads to a deep understanding the state of the arts of recent commercial approaches.

Our approach is basically a generalized version of some latest patented methods from Servo-Robot Inc., the leading company on robotic welding system in the market. In the newly proposed robotic system, both TCP-co-axial sensors and 3D profile sensors are employed to obtaining information about the seam and the robot tracking performance. Moreover, multiple off-line runs of robot programs and synchronization of the measured data are carried out to eliminate certain statistical errors, and this leads to a highly repeatable time-based model of the seam and the robot. The proposed architecture uses incremental pose predication and hence allows both tracking algorithms and compensation algorithms to be easily combined. Depending the adopted algorithms, there are typically two different combinations. The first one combines conventional incremental tracking with passive feedforward compensation. First an off-line measurement of the inherited nonlinear characteristics of an industrial robot is carried out. Both residual errors in high precision seam tracking due to robot nonlinearity (e.g. bursting-type shifts) and compensation procedures are recorded and used to compute an optimized compensation record. During online welding, output of conventional incremental tracking method is then added with interpolated the optimized feedforward compensation data. The second one combines predicative incremental tracking with optimized feedforward compensation. By comparing online measured data with off-line recorded data, it is possible to predict abnormal burst-type shifts of robot path and sudden external disturbance. Therefore a higher success rate can be obtained in an industrial environment which is highly desirable.

Our experiments demonstrate that the robot system can track both linear and nonlinear long seams at a high speed of 100mm/s with Tool Center Point (abbreviated as TCP) error within ±0.1mm.

Keywords: Seam Tracking, Predictive Compensation, Laser Welding, Industrial Robot

Design of a Micro-Displacement Adjustment Support Clamp based on Flexible Hinge Structural Principle

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Abstract

Ultra-precision work table with high performance is widely used in the field of precision manufacture, ultra-precision machining, micro-assembly, bio-cell manipulation, nano-technology. Precision location of workpiece is very important to keep the geometrical and dimensional precision during machining of small workpiece. Micro-displacement adjustment support clamp based on flexible hinge structural principle is a new developed micro-displacement mechanism in the recent years. Its character includes impact structure, small volume, no mechanical friction, no clearance and high displacement resolution (up to 1nm). It is considered as ideal displacement adjustment mechanism in the manufacturing of precision mechanism.

The diameter of shank and helix groove is different. Due to small rigid, the support structure is necessary in the position of shank and helix groove during the groove grinding. The location precision is very important to the machining precision, so the adjustment of coaxiality between shank and helix groove is very important to the geometrical and dimensional precision. A linear displacement adjustment mechanism 'a' and two angular displacement adjustment mechanism 'b' and 'c' are combined to adjust the linear and angular displacements and keep the coaxiality between shank and helix groove, as Fig. 1 shown.

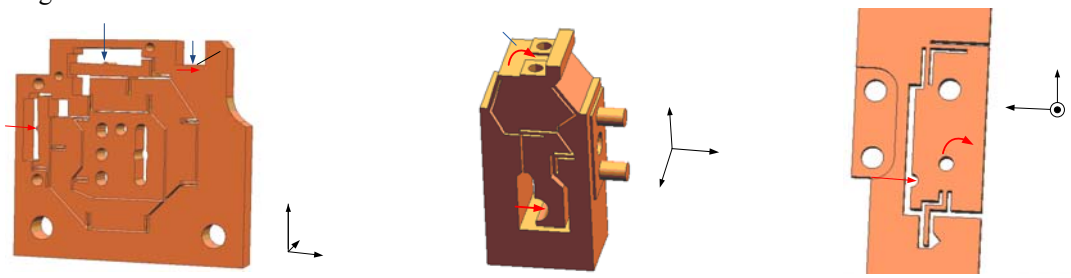

Fig.1 Structure design of flexible hinge

As shown in Fig. 2, it found the relationship between input and output response was almost linear, which implied a good design. For flexible hinge 'a', the equivalent stiffness in the X direction and Y direction are respectively 1.273E-2 μm/μm and 1.783E-2 μm/μm; for flexible hinge 'b' and 'c', the equivalent stiffness are respectively 1.917E-3°/μm and 3.018E-3°/μm.

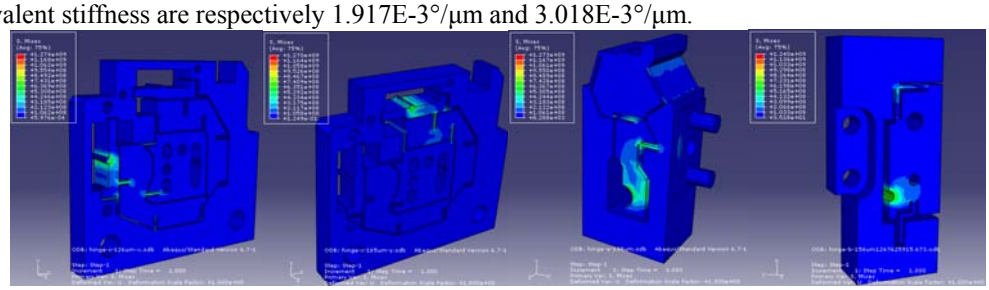

Fig. 2 simulated results

A novel micro-displacement adjustment support clamp was designed for the grinding of small part. It can realize the adjustment of coaxiality between shank and helix groove. The output displacement response due to input displacement and the allowable maximal input displacement were calculated by the aid of finite element method. The relationship map between input displacement and output (linear and angular) displacement were built to guide the application of the flexible hinges.

Keywords: Flexible hinge, Micro-displacement adjustment, Finite element analysis

Input of Z-direction displacement

Output of Z-direction displacement

Support plane of
big V-shape block

Output plane

Output of angular
displacement
around X-axis

Output of X-direction displacement

Core part of the flexible
hinge without outputs

Z

Input of Y-direction
displacement

Geometric Error Analysis and Compensation of Machine Tool Based on Stewart Platform for Machining Large-scale Components

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Abstract: The movable minitype machine tool is used to machine the workpiece, and it uses Stewart mechanism and have five-axis, geometrical errors of which, for example: manufacturing and assembling errors brought by Stewart joints and drive shafts, kinematics errors of both joints and drive shafts, can influence the precision of large-scale components greatly.

In this paper，error factors impacting machine tool geometric error is studied according to Stewart platform kinematic model; when the machine tool machines in a small range, the change of drive shafts is small, assumes that the swing angle of universal joints, together with the composite error of machine tool influenced by measurability and immeasurability factors mentioned above can be considered as linear variation, and the look-up table model will be established using linear interpolation, which can gain the error of discrete cutting-tool position, and the model is used to obtain errors of the position and orientation in arbitrary workspace of machine tool. And then offline calibration method is proposed based on Kalman filter. As shown in figure 1. According to the look-up table model, an offline numerical compensation method is given to compensate the immeasurability and measurability factors. As shown in figure 2. Finally, simulation results demonstrate that the look-up table model are correct and the offline numerical compensation method is feasible.

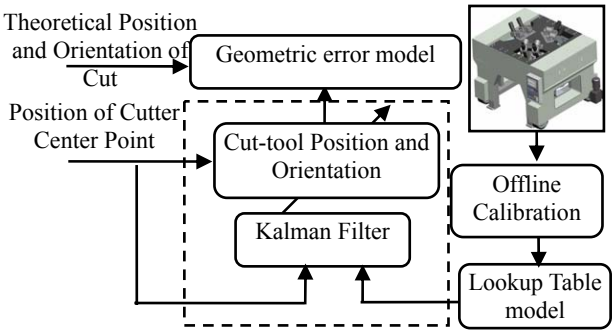

Fig. 1 Adaptive estimation method for error calibration

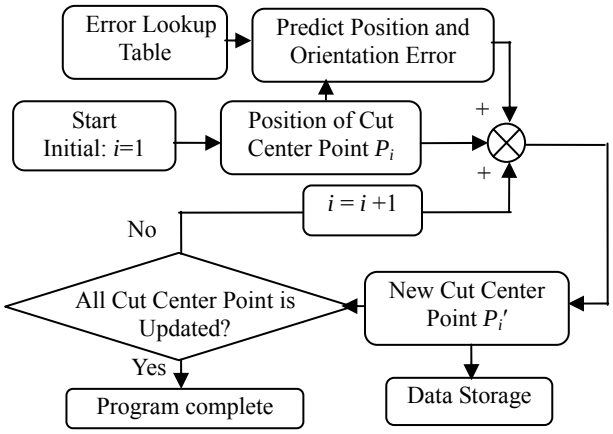

Fig. 2 Numerical compensation method of geometric error

Keywords: Large scale component, Stewart Platform, position and orientation error, Kalman filter, numerical compensation

Using Computer Micro-vision Method to Measure Micro-displacement of Micro-motion Stage with Nanometer Accuracy

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Abstract: The micro-motion stages are widely used in micro/nano manufacturing technology. In this paper, an integrated approach for measuring micro-displacement of micro-motion stage that incorporates motion estimation algorithm into the computer microvision is proposed. At first, the basic principle of the computer microvision measurement is analyzed. Then, a robust multiscale motion estimation algorithm for micro-motion measurement is proposed. Finally, the micro-displacement of the micro-motion stage based on the piezoelectric ceramic actuators and the compliant mechanisms is measured using the integrated approach. The maximal bias of the proposed approach reached 13 nm. Experimental results show that the new integrated method can measure micro-displacement with nanometer accuracy.

Keywords: Displacement measurement, Computer micro-motion, Micro-motion stage, Nanometer accuracy

Application of Air-Coupled Ultrasonic Testing in Inspection of Carbon Fiber Composite Plate*

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Abstract: The received signal of air-coupled ultrasonic is weak and SNR is rather low, because of the great energy loss in the air-solid interface and solid-air interface. Pulse compression and phase-sensitive detection testing are implemented, so the air-coupled ultrasonic C scan imaging detection is realized. The air-coupled ultrasonic imaging detection methods in composite components with different testing modes are researched, the research results are very important to air-coupled ultrasonic in-situ testing. Comparative researsh between pulse wave and continuous wave stimulating mode is studied, the amplititude of continuous cycle stimulating mode is obviously greater than pulse stimulating mode. The peak of echo signal increase 12.5 dB by an average in same peak-peak value of stimulating signal. Different transducer stimulating signal are used to analyzing its impact on the amplitude of echo signal. The results showed that: the signal amplitude in multi cycles continuous wave excitation is strongest, but the number of cycles more than 5 cycles can barely further increasing the signal amplitude. Phase sensitive detector can not only acquire the amplitude of modulated signals, but also can identify the phase of modulated signals. The amplitude and phase of echo signal can be acquired relatively accurate by phase sensitive detection technology in low SNR condition. Experiment results indicated that phase sensitive detector can effectively improve the SNR of test results. Using pulse compression technology, high amplitude received signal can be acquired without increasing the instantaneous output power, and the ability to distinguish echos of system also can be improved. In order to take full advantage of ultrasonic transducer frequency band, some appropriate window function should be added to the stimulating signal. Experiment results indicated that the enhancing effect of SNR with broadband transducer is more obviously, which is coherent with theory result. So broadband transducer would acquire better compression performance in practical testing.

Air-coupled ultrasonic testing system mainly includes: SNAP high-energy ultrasonic testing equipment, air-coupled ultrasonic transducers, industrial computer, high-speed data acquisition card, motion control cards, two-axis scan planes and the corresponding fixture. Pulse compression algorithm can be achieved through a fast convolution processing, so the fast Fourier transform and inverse transform can be used to speed up the calculation process. A 3 mm thick (14 layers) resin-based carbon fiber composite plate is tested by this system. Imaging qualitiy has been greatly improved by pulse compression, compare to the C scan imaging, the SNR increased 8.1 dB. However, but the data processing speed of testing system is decreased, because the decompression is calculated by software. Continuous wave stimulating mode can effectively improve the strength of signal, and appropriate signal processing technology should be adopted to improve the SNR of received signal. Pulse compression technology can enhance the SNR of signal significantly. Common defects in carbon fiber composite materials can be detected by air-coupled ultrasonic testing, with a series of signal enhancement method, it has important practical significance to air-coupled ultrasonic in-situ testing.

Keywords: *Air-coupled ultrasonic, Carbon fiber composite plate, Pulse compression, Phase-sensitivity detector*

Design and analysis of precision-driven unit for nanoindentation and scratch test

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Abstract: Micro/nano positioning and precision-driven technique plays a crucial role in modern technologies including micro/nano mechanics test, scanning tunnel microscopy, atom force microscopy, X-ray lithography, nanoimprint lithography, bio-medicine, micro/nano surgery, and micro/nano surface metrology and characterization. This paper presents a kind of precision-driven unit used for nanoindentation and scratch test which is an important method of micro/nano mechanics test. The unit was composed of piezoelectric actuator and flexure hinge. Piezoelectric actuator was selected as power conversion element and flexure hinge worked as precision transmission elements. When the voltage was applied to piezoelectric actuator, due to the converse piezoelectric effect, it would extend and then push the flexure hinge to output precision elastic deformation. If the applied voltage is cut off, flexure hinges will return to initial position. And then the precision-driven was realized.

In this paper, the CATIA model of the flexure hinge was built and two key design parameters, the thickness *t* and the width *w* were introduced firstly. Then effects of the two parameters on performances of flexure hinge were analyzed via finite element method and the results showed that the output displacement was a monotonic decreasing function of the thickness *t* and width *w*. However, stiffness was a monotonic increasing function of the thickness *t* and width *w*. Static analysis of flexure hinge was carried out to test the strength of structure.From the analysis results we can see that the maximum stress for different thickness *t* and width *w* was less than permissible stress of Spring Steel 65Mn being 432MPa.So the designed structure had enough strength. Also modal analysis was done to examine dynamic performance of flexure hinge. The width *w* affected the first order mode frequency of the flexure hinge more than the thickness *t*,but for different thickness *t* and width *w*, majority of the first order mode frequency was over 3800Hz which indicated that the flexure hinge had good stability at low frequency condition. And the first three order mode shapes of the flexure hinge under the condition that *t*=0.7mm and *w*=8mm were obtained. The flexure hinge was processed through wire-cutting under the condition that *t*=0.7mm and *w*=8mm.Then the output performance of the precision-driven unit was tested. The output displacement was measured by LK-G10 type laser displacement sensor with resolution of 10nm. Experimental results showed that the maximum output displacement was about 12.91um when the voltage was 120V and the output displacement was about 0.5um when the voltage was 5V.The hysteresis of the designed unit caused by hysteresis of piezoelectric ceramic was analyzed .The maximum difference of displacement is about 1.15V at voltage 45V and the hysteresis was about 0.0891 which was very small. So, this unit can be used for nanoindentation/scratch test as well as other fields about nano-fabrication and nano-manipulation.

Keywords: Flexure hinge, Piezoelectric actuator, Static analysis, Modal analysis, Hysteresis

An Online Video Inspection System for LCD Projectors

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Abstract

In the process of assembly line production, a wide range of product testing, production monitoring and accessory parts identification applications will be involved. In the early stage of the industrial assembly line production, an artificial recognition method was widely used. This detecting method would normally be constrained by various conditions and factors. A sort of industrial image inspection system based on machine vision provides an available frame of reference under this circumstance. The study on the industrial images inspection system mainly focuses on the on-line detection and control during the production process. By capturing images and analyzing the morphological and texture characteristics of the tested object, the characteristic parameters of the object are obtained. Thus, it can provide a foundation for decision making in a controlling system.

In this paper, we have developed an automatic inspection system based on machine vision technology, as shown in Fig. 1. The system chooses a high-speed image acquisition module and a PC workstation as the platform, and several detection tool modules for captured images are developed, such as preprocessing, edge detection and contour extraction and template matching. The main functions of system software include detection of system settings, image processing and running the detection.

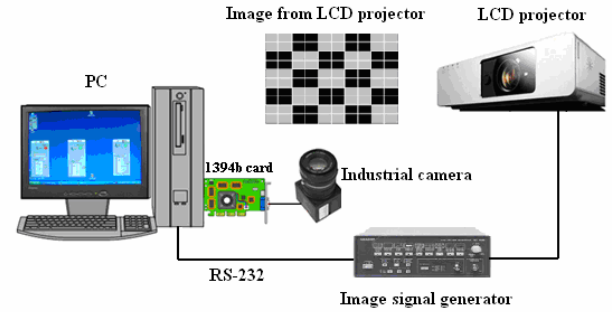

Fig. 1 The online video inspection system for LCD projectors

To realize the rapid and efficient video inspection, we have completed some tests like: dust inspection, LCD panel defect inspection, focus inspection, RGB movement confirmation and comprehensive inspection. Dust inspection is used to detect whether the liquid crystal panel has dust contamination. LCD panel defect inspection detects the defective pixel on LCD panel. Focus inspection implements the definition detection of projectors. RGB movement confirmation inspects whether the various items of movement in POSITION MENU and PICTURE MENU are normal. And comprehensive inspection is used for detecting image distortion, brightness/contrast, hue and saturation etc.

The image inspection system has a good versatility and flexibility, and meets the requirements of inspection. At the same time, through simulation experiments in the laboratory, we have tested the working performance of several projectors, the result of which is basically the same as that of artificial inspection. It is found that this online inspection system has achieved satisfactory results. The simulation result demonstrates the generality and stability of the system, and satisfies the design requirements of real-time inspection, fast speed and high accuracy. The developed system is a powerful tool for similar inspection tasks

Keywords: LCD projector, Image Processing, Inspection

Topological Structural Analysis of Metamorphic Mechanism Based on Generalized Incidence Matrix Operations

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Abstract: In order to overcome the drawback of adjacency matrix of monochrome topological graph that can only express topological structures of single-joint mechanisms, whose corresponding operation of the adjacency matrix can only be suitable to the configuration change of single-joint metamorphic mechanisms, A bicolored graph is presented to express structures of both single-joint and multi-joint metamorphic mechanisms. An operation of the generalized incidence matrix (GIM) based on bicolored graph is proposed. The operation steps and rules are given. The accuracy of the operation to express the topological structure and analyze the configuration change of metamorphic mechanisms by GIM is illustrated by some examples.

Keywords: Metamorphic Mechanism, Topological Graph, Generalized Incidence matrix, Configuration analysis

Tolerance optimization based on BP-neural network and genetic algorithm

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Abstract: In order to satisfy the product functional requirement and the least manufacturing cost, allocating components tolerances effectively is one of the main objectives in the tolerance design research filed. Since the cost-tolerance experimental

data is difficult to obtain, it becomes very important to infer the cost-tolerance relationship of the non-experimental data based on the limited experimental data. Due to the highly nonlinear relationship between the product tolerance and the manufacturing cost, a comprehensive tolerance optimization method based on BP-neural network in conjunction with genetic algorithm is proposed. In the optimization process, the BP-neural network is trained using the sample data to simulate the tolerance-cost function first. The model of the network is designed by using the tolerance value and the process type as the two inputs and the cost as the corresponding output. The node number of the hidden layer is 10. And then the genetic algorithm is applied to optimize the tolerance allocation. The genetic algorithm takes the results of trained neural network and technical requirements as constraints, and the minimum of component total cost as the objective. Based on the theories mentioned above, the method is applied in the VC environment while transferring the .dll file built by the Matlab. The tolerance data from the neural network is used for the system. To verify the feasibility and superiority of the proposed method, the tolerance design of the gear case is taken as an example. To prove the superiority of the comprehensive tolerance optimization method based on the integration of BP neural network and genetic algorithm, the tolerance results of other different methods are tested and compared against the proposed method. The result of the application proves that the proposed method is able to produce tolerance optimization economically and accurately, and has the advantage over the traditional methods.

Keywords: Cost-tolerance function; tolerance optimization; BP-neural network; genetic algorithm

Energy Efficient Data Transmission for Manufacturing System Health Monitoring

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Abstract: This paper presents an energy efficient method for data transmission based on the Walsh function, which compresses the data streams to be transmitted. The approach is geared towards wireless sensor nodes that possess limited energy resources and is intended for

use in wireless sensor networks for monitoring manufacturing machines. An algorithm for adaptively scaling sensor signals through Walsh coding functions is presented. Theoretical background of the method has been introduced and performance measures have been established through experimental study of vibration signals recorded from rolling element bearings. Significant reduction in the energy consumed during signal transmission is reported.

Keywords: Energy-aware systems, Signal compression, Walsh transform, Wireless sensor networks.

Study on electrical pulse removing residual stress in 45 steel quenched specimens

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Abstract: In order to investigate the effect of electric pulses on removing residual stress in metal materials, high-energy electrical pulse was generated by energy storage capacitors. Electric pulses was conducted to treat quenched cold-rolled specimens of 45 high-quality carbon structural steel. Hole-drilling method was taken to detect residual stress in the specimens before and after electropulsing treatment (EPT). The pulse waveform used for electropulsing treatment was exponential decay of oscillatory shape. The first peak of the current density was 15.3kA/mm^2, the discharge duration of single processing was less than 0.8ms, and the frequency of discharge treatment was 0.5Hz. The experiment and measurement results indicate that, the residual stress in two principal directions of 45 steel quenched specimens are reduced significantly, and distributed much more evenly.

Keywords: Electropulsing Treatment, Residual Stress, Hole-drilling Method, Electronic Wind, Dislocation

Fuzzy Miner rule considering the damage and strengthening of low-amplitude loads under different load sequences

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Abstract: A reliable lifetime prediction is particularly important in the design, safety assessments and optimization of engineering materials and structures. Current fatigue analyses of metallic structures undergoing variable amplitude load histories, including many engineering components operating in aviation, power-generating, and other industries, are mostly based on linear cumulative damage concepts. Damage accumulation in materials is very important, but very challenging to characterize in a meaningful and reliable manner. Although many damage models have been put forward, the linear damage rule, also called the Palmgren-Miner rule (just the Miner rule for short), is commonly used in analyzing cumulative fatigue damage due to its simplicity. However, the linear damage rule is widely acknowledged to be inadequate, this is partially based upon its empirical nature and it may result in the evidence errors because the mechanisms of loading sequence and load-interaction effects that occur during the fatigue loading history can not be considered within this theory in practical engineering application. Especially when high-amplitude loadings are applied first, followed by low-amplitude loadings until failure occurs, therefore, its indiscriminate use can lead to non-conservative situations. The linear damage rule also neglects the damage induced by any stress below the fatigue limit. The objectives of the present work are to develop a new accumulation damage model, a fuzzy Miner rule, including that (1) to investigate the damage induced by any stress below the fatigue limit; (2) also to study systematically (a) the load sequence effects that occur during the fatigue loading history and (b) the strengthening effect, pay attention to the strengthening and damaging of low-amplitude loads below the fatigue limit. It is fuzzy when the stress that the structural components subjected to is slightly lower than the fatigue limit. In the fuzzy rules, the fuzzy information cannot be analyzed and dealt with until the fuzziness is quantitatively described by the membership functions. Due to the rule of fatigue phenomenon, increasing membership functions should be selected to analyze the fuzziness of fatigue damage to the component. In order to apply the proposed model conveniently, different membership functions are investigated, which have important influence on the result of estimating fatigue life. According to the traditional Miner rule, it should be emphasized that the present work has the advantage of reflecting the influence of load sequence on the fatigue life and considering the strengthening and damaging under low-amplitude loads below the fatigue limit, which can account for the whole process of fatigue damage through using fuzzy mathematics. Choosing an optimal membership function plays a pivotal role in the life prediction using fuzzy

Miner rule. Moreover, the validity and accuracy of the proposed method is evaluated through a comparison of predicted and observed fatigue life distributions for metallic specimen subjected to various multilevel and two-stress level uniaxial fatigue loadings with experimental data from existing literature. And the law of selecting membership function for different load spectrum is found and the errors of predicted life are reduced. To improve the accuracy of life prediction using the proposed model, the determination of membership function and its related parameters can be optimized by comparison of prediction errors. It proved that the predicted fatigue life by the proposed method is more accurate than traditional way. Besides, to examine the application of this model in other cases such as life prediction under random loading spectrum, choosing of membership functions and the reliability will be further evaluated.

Key words: low-amplitude loading strengthening; Miner rule; life prediction; membership function; load sequence

A Durability Analysis Method for Railway Carbody Structure Subjected to Dynamically Loads

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Abstract: Modern railway vehicles in new product development requires not only the structure has a good dynamic characteristics, reliability, durability, but also for the structure as lightweight, in order to increase vehicle safety，reduce energy consumption and improve product competitiveness. As the high speed railway market increasingly competitive, the carbody is required to shorten product development cycles and costs. And the light weight and durability of the carbody structure design are paid more and more attention. Compared with the traditional static strength/stiffness and fatigue design method, the method, which is given the random dynamic loads, the structure fatigue life prediction of complex vehicle systems are more responsive to the actual service environment. In last years, structural fatigue design and research still focussed on the traditional static strength / stiffness design and conventional fatigue design methods. It is gradually turned to consider the structure dynamic strength / stiffness and dynamic characteristics of the full vehicle structure under random vibration loads. At present, durability design of the railway carbody structure has mainly depend on the traditional fatigue design method, did not fully take into account the full vehicle dynamic characteristics.

However, the railway carbody structure durability design plays an important role in the modern railway industry not only in the design of vehicle structures' safe reliability but also their ride comfort requirement. A new analytical method has been developed to calculate railway carbody stresses and fatigue life prediction by combining full vehicle multibody dynamic simulation with finite element method in this paper. The method has the following features: (1) Full vehicle Multi-body Dynamics (MBD) ,which the aerodynamic effects is considered in the vehicle model and used to model and simulate complex car body's dynamic property; (2) Multi-disciplinary optimization algorithm is used to study the interaction between dynamic strength/stiffness and durability design; (3)Using the structure finite element method (FEM) and Miner damage rules to identify the critical areas and damage locations within carbody structure.

In general, several current numerical calculation methods are used to evaluate the carbody fatigue life and durability .It also was compared the simulation results with field stress test results. In general, these results indicate that the method proposed here can effectively to obtain railway car body's typical load spectrum and performing durability design.

Keywords: Multibody systems; durability design; multi-disciplinary optimization.

Effects of Forming Process on Automotive Wheel Strength Analysis

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Abstract: The steel wheel is assembled with rim and spoke, which is one of the most important parts of the vehicle, has a major impact on a variety of automobile properties, such as safety and reliability etc, while the wheel centre disc is obtained through the processes of drawing forming and inverse-drawing forming, which will produce stamping effects such as thickness variation, material hardening and residual stress etc during the stamping process. So the stamping effects will have a great impact on the wheel structural performance and should be taken into account when performing the structural analysis. The conventional methods of wheel strength analysis ignored the effects of forming process, which is not consonant with the reality and may lead to the inaccurate results. Normally, the structural analysis cannot inherit the stamping effects due to heterogeneous codes used in forming simulation and strength analysis. The numerical simulation of stamping requires a nonlinear FEM code like LS-DYNA due to the non-linearity accompanying with the stamping process, while for structural FEM analysis, another type of FEM code like ANSYS are normally used. The different data organization used in these two types of FEM analysis makes it difficult to obtain the stamping effects and further apply these effects in the subsequent strength analysis. This paper proposes adopting a mapping method to integrate the stamping effects into the structure analysis.

In this paper, The numerical forming simulation based on incremental method and the mapping algorithm of mesh information are incorporated into structure FEM analysis to construct a 'fine' simulation scheme which can consider the effect of forming process and improve the simulation accuracy of the steel wheel.

Based on the elastoplasticity incremental theory and by adopting the dynamic explicit finite element method, the drawing process and inverse-drawing process of the wheel centre disc are numerically simulated with the software DYNAFORM, and a mapping method has been adopted to transfer the forming simulation result onto the structural analysis model, After the mapping process is finished, a stress file containing six stress components of all elements of the structural FEM analysis model is exported, which is LS-DYNA format. The stress file is converted to ANSYS format and was imported to the structural FEM analysis model as initial conditions and the wheel structure strength is analyzed with the ANASYS structure analysis module. By integrating these two domains independent CAE tools, the forming effects generated from stamping can be imported into the structural analysis environment.

The simulation results show that the present scheme is useful and powerful in the steel wheel strength analysis process, and any stamped structure needing to consider forming residual stress can be analyzed when loaded all kinds of weight. The results also verified that because the direction of the forming residual stress and the direction of the bending stress are of not all the same, the force state of the steel wheel should be superposition of these two kinds of stresses; When the directions of these two stresses are of the same at some nodes, the two kinds of stresses at these nodes will be added, thus the von mises stress at these nodes will increase; while the directions of these two kinds of stresses at some nodes are opposite, the two kinds of stresses at these nodes will be subtracted, thus the von mises will decrease. As a hole, the distribution area of high stress spread, the value and the direction of stress have been redistributed by considering the residual stress, thus would be more close to the reality of the wheel. In order to increase the simulation accuracy and reliability of strength analysis, the forming effects of stamped wheel structure should be considered.

It should also be emphasized that the proposed approach are generally applicable to a variety of other structural performance analysis such as strength, stiffness, dent-resistance and crashworthiness. So the integrated analysis method proposed here has some practical significance and reference value so as to in-depth study of the structural performance analysis of stamped structure.

Keywords: Automotive wheel, Strength analysis, Forming simulation, Residual stress, mapping algorithm