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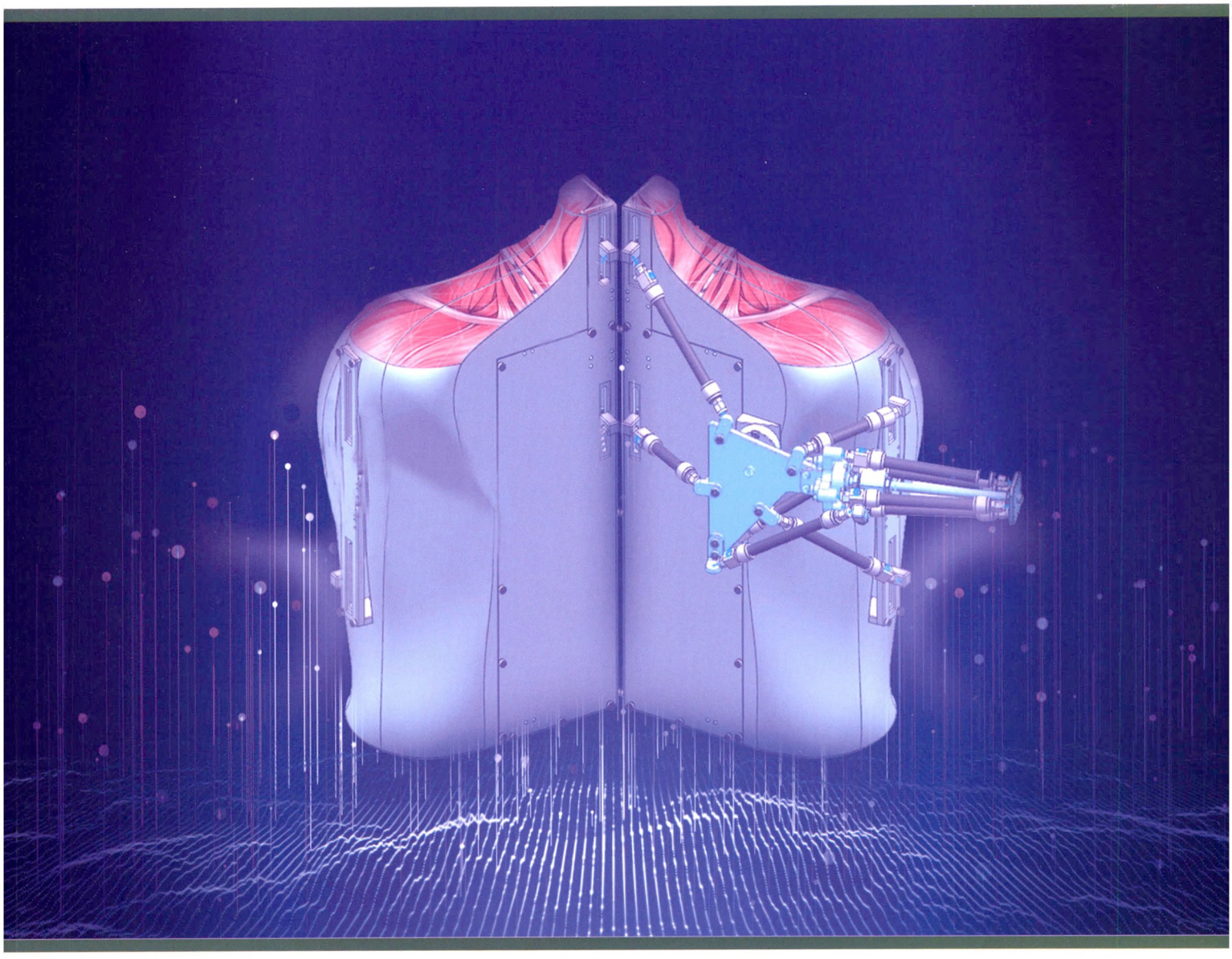
ISSN 1000-9345 · CN 11-2737/TH · CODEN CJMEER

CHINESE JOURNAL OF MECHANICAL ENGINEERING®



DOI: 10.1186/s10033-019-0394-y

Fuzzy Torque Control of the Bionic Flexible Manipulator Actuated by Pneumatic Muscle Actuators.

Kai Liu • Yining Chen • Jiaqi Xu • Yang Wu • Yonghua Lu • Dongbiao Zhao

CJME
2019 Vol. 32
October

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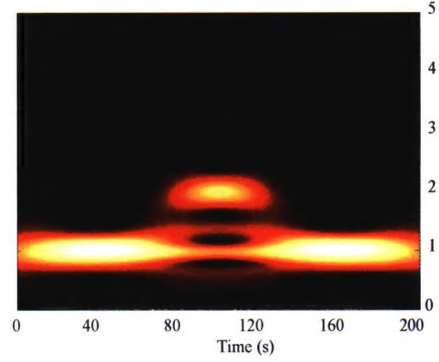
CHINESE JOURNAL OF MECHANICAL ENGINEERING

Review

(2019)32:75
DOI: 10.1186/s10033-019-0388-9

Signal-Based Intelligent Hydraulic Fault Diagnosis Methods: Review and Prospects. Juying Dai • Jian Tang • Shuzhan Huang • Yangyang Wang

Abstract: Hydraulic systems have the characteristics of strong fault concealment, powerful nonlinear time-varying signals, and a complex vibration transmission mechanism; hence, diagnosis of these systems is a challenge. To provide accurate diagnosis results automatically, numerous studies have been carried out. Among them, signal-based methods are commonly used, which employ signal processing techniques based on the state signal used for extracting features, and further input the features into the classifier for fault recognition. However, their main deficiencies include the following: (1) The features are manually designed and thus may have a lack of objectivity. (2) For signal processing, feature extraction and pattern recognition are conducted using independent models, which cannot be jointly optimized globally. (3) The machine learning algorithms adopted by these methods have a shallow architecture, which limits their capacity to deeply mine the essential features of a fault. As a breakthrough in artificial intelligence, deep learning holds the potential to overcome such deficiencies. Based on deep learning, deep neural networks (DNNs) can automatically learn the complex nonlinear relations implied in a signal, can be globally optimized, and can obtain the high-level features of multi-dimensional data. In this paper, the main technology used in an intelligent fault diagnosis and the current research status of hydraulic system fault diagnosis are summarized and analyzed. The significant prospect of applying deep learning in the field of intelligent fault diagnosis is presented, and the main ideas, methods, and principles of several typical DNNs are described and summarized. The commonality between a fault diagnosis and other issues regarding typical pattern recognition are analyzed, and research ideas for applying DNNs for hydraulic fault diagnosis are proposed. Meanwhile, the research advantages and development trend of DNNs (both domestically and overseas) as applied to an intelligent fault diagnosis are reviewed. Furthermore, the fault characteristics of a complex hydraulic system are summarized and discussed, and the key problems and possible research ideas of applying DNNs to an intelligent hydraulic fault diagnosis are presented and comprehensively analyzed.



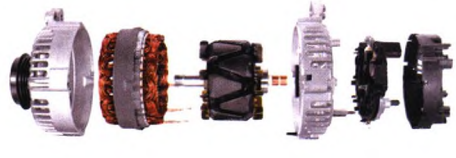
Intelligent Manufacturing Technology

(2019)32:82
DOI: 10.1186/s10033-019-0395-x

Non-destructive Measurement of Magnetic Properties of Claw Pole.

Chengliang Hu • Xuejiao Bai • Minjun Tang • Xiaofeng Tang • Zhen Zhao

Abstract: The magnetic properties of the claw pole have a direct effect on the output power of a generator. Many methods can be used to measure these magnetic properties, each with its own advantages, but an important shortcoming is that all are destructive. In this study, a new non-destructive method to measure the magnetic properties of claw pole was proposed and a corresponding testing set-up was designed. A finite-element model was constructed to simulate the measurement process. Results proved that the measured magnetization-like curves had good agreement with the trend of the input magnetic curves and the effect of the positioning error in the measuring process could be neglected. To further validate the new method, seven types of claw poles of different materials subjected to different heat-treatment processes were forged and tested by both the new method and the conventional ring-sample method. Compared with the latter, the new method showed better consistency, relatively higher accuracy, and much stronger stability of measurement results; however, its sensitivity needs to be improved. The effects of material compositions and heat-treatment parameters on the magnetic properties of the claw pole were briefly analyzed.



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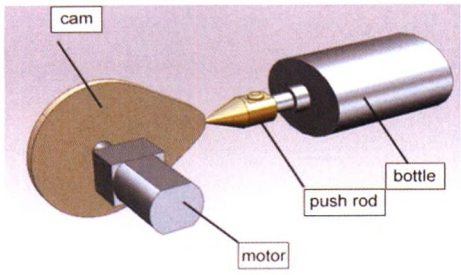
(2019)32:86
DOI: 10.1186/s10033-019-0400-4

Design Around Bundle Patent Portfolio Based on Technological Evolution.

Hui Li • Jiefeng Yuan • Runhua Tan • Qingjin Peng

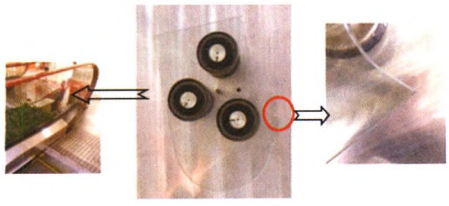


Abstract: Product innovation can be achieved by analyzing leading products patents in the market. Different methods have been proposed for design around patent, commonly using the elimination or replacement of a single patent element. However, the existing research fails to restore the position and function of the design around object in the original patent portfolio of enterprises, which often leads to the phenomenon of evading one patent and violating another. This paper proposes a method for design around patent through using the fusion of technologies of the evolution theory and bundle-type patent portfolio analysis in the initial stage of product development. The object system is analyzed to select technical opportunities through the evolutionary path of technologies and functional trimming methods to achieve circumvent barriers of bundle-type patents. The bundle patent portfolio is analyzed for the product evolution with a radar map. The technological evolution path is combined with the TRIZ innovation method to identify and solve the design problem. Patentability of the new design is evaluated using the patent system rules for innovative scheme difference from the original patent portfolio. The method is verified in a case study for the design of a glass-wiping robot. The design solution has been patented.

(2019)32:87
DOI: 10.1186/s10033-019-0398-7

Corner Transition Toolpath Generation Based on Velocity-Blending Algorithm for Glass Edge Grinding.

Kun Ren • Yujia Pan • Danyan Jiang • Jun Pan • Wenhua Chen • Xuxiao Hu



Abstract: Sharp corners usually are used on glass contours to meet the highly increasing demand for personalized products, but they result in a broken wheel center toolpath in edge grinding. To ensure that the whole wheel center toolpath is of G1 continuity and that the grinding depth is controllable at the corners, a transition toolpath generation method based on a velocity-blending algorithm is proposed. Taking the grinding depth into consideration, the sharp-corner grinding process is planned, and a velocity-blending algorithm is introduced. With the constraints, such as traverse displacement and grinding depth, the sharp-corner transition toolpath is generated with a three-phase motion arrangement and with confirmations of the acceleration/deceleration positions. A piece of glass with three sharp corners is ground on a three-axis numerical-control glass grinding equipment. The experimental results demonstrate that the proposed algorithm can protect the sharp corners from breakage efficiently and achieve satisfactory shape accuracy. This research proposed a toolpath generation method based on a velocity-blending algorithm for the manufacturing of personalized glass products, which generates the transition toolpath as needed around a sharp corner in real time.

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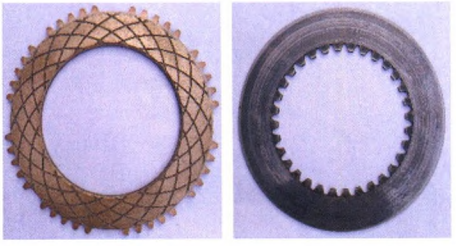
(2019)32:80
DOI: 10.1186/s10033-019-0393-z

Theoretical Model and Experimental Research on Friction and Torque Characteristics of Hydro-viscous Drive in Mixed Friction Stage.

Hongwei Cui • Qiliang Wang • Zisheng Lian • Long Li

Abstract: The hydro-viscous drive (HVD) has been widely used in fan transmission in vehicles, fans, and scraper conveyors for step-less speed regulation or soft starting. In the mixed friction stage, the contact, friction, and torque characteristics of friction pairs are very complex and change at any time. The characteristics of the frictional and hydrodynamic lubrication states were studied in order to calculate and predict the friction and torque characteristics of the friction pairs in the mixed friction stage. The fluid torque was calculated by applying the average shear stress model and the load-carrying capacity of asperity was determined on the basis of the fractal contact theory. In addition, the contact friction coefficient of the friction pairs was taken into consideration and measured by using the MM1000-III friction and wear testing machine. The asperity friction torque and total torque in the mixed friction stage were obtained and finally, the test rig for the torque characteristics was set up. The results show that the contribution to the total torque is shared by the oil film and the asperity friction. The friction coefficient decreases sharply at first and then increases with a change in the relative rotational speed, following the Stribeck curve closely, and the contact frictional coefficient slowly decreases with increase in the pressure between the friction pairs. The torque between the friction pairs is provided by the asperity friction, and the torque due to the oil film reduces to zero. When the thickness of the oil film is small, a major contribution to the total torque is due to the asperity friction. The total torque also increases with the decrease in the film thickness ratio. Therefore, by theoretical analysis and experimental verification, the torque of the friction pairs in the mixed friction stage can be accurately calculated using the average shear stress model and asperity friction torque model.

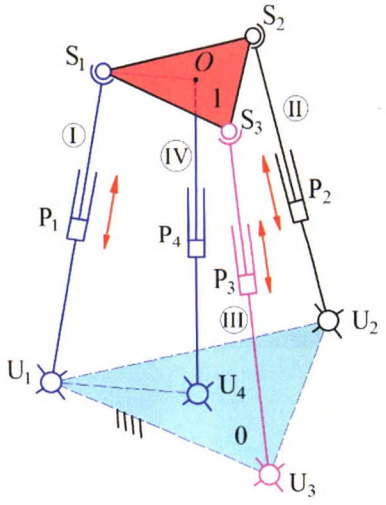


Mechanism and Robotics

(2019)32:89
DOI: 10.1186/s10033-019-0403-1

Type Synthesis of 1T2R Parallel Mechanisms Using Structure Coupling-Reducing Method. Haitao Liu • Ke Xu • Huiping Shen • Xianlei Shan• Tingli Yang

Abstract: Direct kinematics with analytic solutions is critical to the real-time control of parallel mechanisms. Therefore, the type synthesis of a mechanism having explicit form of forward kinematics has become a topic of interest. Based on this purpose, this paper deals with the type synthesis of 1T2R parallel mechanisms by investigating the topological structure coupling-reducing of the 3UPS&UP parallel mechanism. With the aid of the theory of mechanism topology, the analysis of the topological characteristics of the 3UPS&UP parallel mechanism is presented, which shows that there are highly coupled motions and constraints amongst the limbs of the mechanism. Three methods for structure coupling-reducing of the 3UPS&UP parallel mechanism are proposed, resulting in eight new types of 1T2R parallel mechanisms with one or zero coupling degree. One obtained parallel mechanism is taken as an example to demonstrate that a mechanism with zero coupling degree has an explicit form for forward kinematics. The process of type synthesis is in the order of permutation and combination; therefore, there are no omissions. This method is also applicable to other configurations, and novel topological structures having simple forward kinematics can be obtained from an original mechanism via this method.



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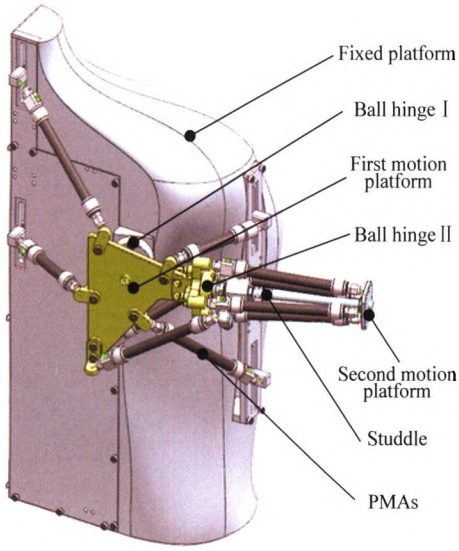
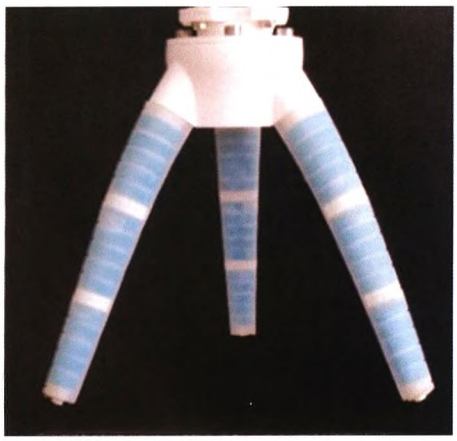


(2019)32:79
DOI: 10.1186/s10033-019-0394-y

Fuzzy Torque Control of the Bionic Flexible Manipulator Actuated by Pneumatic Muscle Actuators.

Kai Liu • Yining Chen • Jiaqi Xu • Yang Wu • Yonghua Lu • Dongbiao Zhao

Abstract: A bionic flexible manipulator driven by pneumatic muscle actuator (PMA) can better reflect the flexibility of the mechanism. Current research on PMA mainly focuses on the modeling and control strategy of the pneumatic manipulator system. Compared with traditional electro-hydraulic actuators, the structure of PMA is simple but possesses strong nonlinearity and flexibility, which leads to the difficulty in improving the control accuracy. In this paper, the configuration design of a bionic flexible manipulator is performed by human physiological map, the kinematic model of the mechanism is established, and the dynamics is analyzed by Lagrange method. A fuzzy torque control algorithm is designed based on the computed torque method, where the fuzzy control theory is applied. The hardware experimental system is established. Through the co-simulation contrast test on MATLAB and ADAMS, it is found that the fuzzy torque control algorithm has better tracking performance and higher tracking accuracy than the computed torque method, and is applied to the entity control test. The experimental results show that the fuzzy torque algorithm can better control the trajectory tracking movement of the bionic flexible manipulator. This research proposes a fuzzy torque control algorithm which can compensate the error more effectively, and possesses the preferred trajectory tracking performance.



(2019)32:78
DOI: 10.1186/s10033-019-0392-0

A Novel Pneumatic Soft Gripper with a Jointed Endoskeleton Structure.

Zhaoping Wu • Xiaoning Li • Zhonghua Guo

Abstract: In current research on soft grippers, pneumatically actuated soft grippers are generally fabricated using fully soft materials, which have the advantage of flexibility as well as the disadvantages of a small gripping force and slow response speed. To improve these characteristics, a novel pneumatic soft gripper with a jointed endoskeleton structure (E-Gripper) is developed, in which the muscle actuating function has been separated from the force bearing function. The soft action of an E-Gripper finger is performed by some air chambers surrounded by multilayer rubber embedded in the restraining fiber. The gripping force is borne and transferred by the rigid endoskeleton within the E-Gripper finger. Thus, the gripping force and action response speed can be increased while the flexibility is maintained. Through experiments, the bending angle of each finger segment, response time, and gripping force of the E-Gripper have been measured, which provides a basis for designing and controlling the soft gripper. The test results have shown that the maximum gripping force of the E-Gripper can be 35 N, which is three times greater than that of a fully soft gripper (FS-Gripper) of the same size. At the maximum charging pressure of 150 kPa, the response time is 1.123 s faster than that of the FS-Gripper. The research results indicate that the flexibility of a pneumatic soft gripper is not only maintained in the case of the E-Gripper, but its gripping force is also obviously increased, and the response time is reduced. The E-Gripper thus shows great potential for future development and applications.

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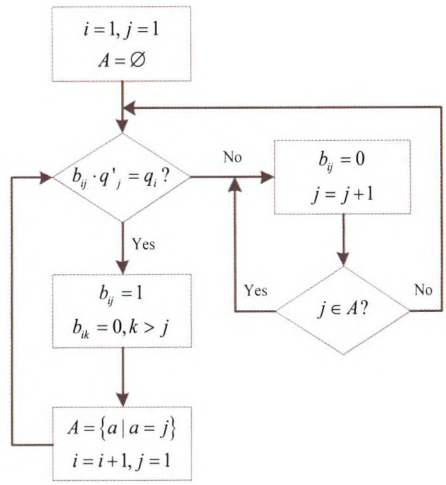
DOI: 10.1186/s10033-019-0391-1

A New Flexible Multibody Dynamics Analysis Methodology of Deployable Structures with Scissor-Like Elements.

Qi'an Peng • Sanmin Wang • Changjian Zhi • Bo Li

Abstract: There are vast constraint equations in conventional dynamics analysis of deployable structures, which lead to differential-algebraic equations (DAEs) solved hard. To reduce the difficulty of solving and the amount of equations, a new flexible multibody dynamics analysis methodology of deployable structures with scissor-like elements (SLEs) is presented. Firstly, a precise model of a flexible bar of SLE is established by the higher order shear deformable beam element based on the absolute nodal coordinate formulation (ANCF), and the master/slave freedom method is used to obtain the dynamics equations of SLEs without constraint equations. Secondly, according to features of deployable structures, the specification matrix method (SMM) is proposed to eliminate the constraint equations among SLEs in the frame of ANCF. With this method, the inner and the boundary nodal coordinates of element characteristic matrices can be separated simply and efficiently, especially on condition that there are vast nodal coordinates. So the element characteristic matrices can be added end to end circularly. Thus, the dynamic model of deployable structure reduces dimension and can be assembled without any constraint equation. Next, a new iteration procedure for the generalized-α algorithm is presented to solve the ordinary differential equations (ODEs) of deployable structure. Finally, the proposed methodology is used to analyze the flexible multi-body dynamics of a planar linear array deployable structure based on three scissor-like elements. The simulation results show that flexibility has a significant influence on the deployment motion of the deployable structure. The proposed methodology indeed reduce the difficulty of solving and the amount of equations by eliminating redundant degrees of freedom and the constraint equations in scissor-like elements and among scissor-like elements.



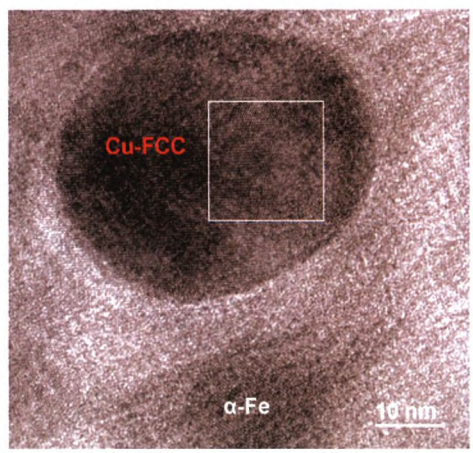
Smart Materials

(2019)32:81
DOI: 10.1186/s10033-019-0397-8

High-resolution Transmission Electron Microscopy Characterization of the Structure of Cu Precipitate in a Thermal-aged Multicomponent Steel.

Lizhan Han • Qingdong Liu • Jianfeng Gu

Abstract: High-dispersed nanoscale Cu precipitates often contribute to extremely high strength due to precipitation hardening, and whereas usually lead to degraded toughness for especially ferritic steels. Hence, it is important to understand the formation behaviors of the Cu precipitates. High-resolution transmission electron microscopy (TEM) is utilized to investigate the structure of Cu precipitates thermally formed in a high-strength low-alloy (HSLA) steel. The Cu precipitates were generally formed from solid solution and at the crystallographic defects such as martensite lath boundaries and dislocations. The Cu precipitates in the same aging condition have various structure of BCC, 9R and FCC, and the structural evolution does not greatly correlate with the actual sizes. The presence of different structures in an individual Cu precipitate is observed, which reflects the structural transformation occurring locally to relax the strain energy. The multiply additions in the steel possibly make the Cu precipitation more complex compared to the binary or the ternary Fe-Cu alloys with Ni or Mn additions. This research gives constructive suggestions on alloying design of Cu-bearing alloy steels.



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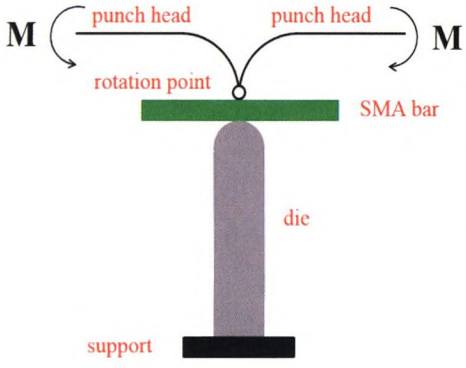
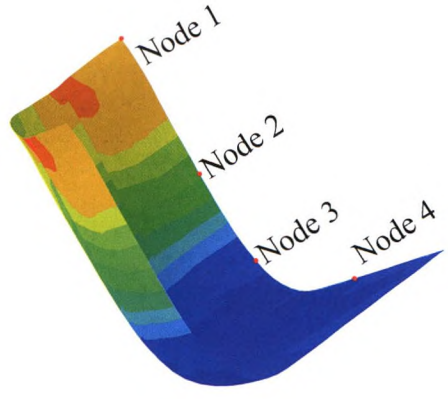


(2019)32:84
DOI: 10.1186/s10033-019-0401-3

Finite Element Method on Shape Memory Alloy Structure and Its Applications.

Bo Zhou • Zetian Kang • Zhiyong Wang • Shifeng Xue

Abstract: It is significant to numerically investigate thermo-mechanical behaviors of shape memory alloy (SMA) structures undergoing large and uneven deformation for they are used in many engineering fields to meet special requirements. To solve the problems of convergence in the numerical simulation on thermo-mechanical behaviors of SMA structures by universal finite element software. This work suppose a finite element method to simulate the super-elasticity and shape memory effect in the SMA structure undergoing large and uneven deformation. Two scalars, named by phase-transition modulus and equivalent stiffness, are defined to make it easy to establish and implement the finite element method for a SMA structure. An incremental constitutive equation is developed to formulate the relationship of stress, strain and temperature in a SMA material based on phase-transition modulus and equivalent stiffness. A phase-transition modulus equation is derived to describe the relationship of phase-transition modulus, stress and temperature in a SMA material during the processes of martensitic phase transition and martensitic inverse phase transition. A finite element equation is established to express the incremental relationship of nodal displacement, external force and temperature change in a finite element discrete structure of SMA. The incremental constitutive equation, phase-transition modulus equation and finite element equation compose the supposed finite element method which simulate the thermo-mechanical behaviors of a SMA structure. Two SMA structures, which undergo large and uneven deformation, are numerically simulated by the supposed finite element method. Results of numerical simulation show that the supposed finite element method can effectively simulate the super-elasticity and shape memory effect of a SMA structure undergoing large and uneven deformation, and is suitable to act as an effective computational tool for the wide applications based on the SMA materials.



(2019)32:76
DOI: 10.1186/s10033-019-0390-2

Prediction of Eight Earings in Deep Drawing of 5754O Aluminum Alloy Sheet.

Haibo Wang • Mingliang Men • Yu Yan • Min Wan • Qiang Li

Abstract: Earings appear easily during deep drawing of cylindrical parts owing to the anisotropic properties of materials. However, current methods cannot fully utilize the mechanical properties of material, and the number of earings obtained differ with the simulation methods. In order to predict the eight-earing problem in the cylindrical deep drawing of 5754O aluminum alloy sheet, a new method of combining the yield stress and anisotropy index (*r*-value) to solve the parameters of the Hill48 yield function is proposed. The general formula for the yield stress and *r*-value in any direction is presented. Taking a 5754O aluminum alloy sheet as an example in this study, the deformation area in deep drawing is divided into several equal sectorial regions based on the anisotropy. The parameters of the Hill48 yield function are solved based on the yield stress and *r*-value simultaneously for the corresponding deformation area. Finite element simulations of deep drawing based on new and existing methods are carried out for comparison with experimental results. This study provides a convenient and reliable way to predict the formation of eight earings in the deep drawing process, which is expected to be useful in industrial applications. The results of this study lay the foundation for the optimization of the cylindrical deep drawing process, including the optimization of the blank shape to eliminate earing defects on the final product, which is of great importance in the actual production process.

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Advanced Transportation Equipment

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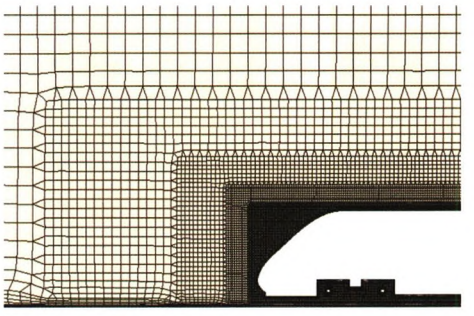
DOI: 10.1186/s10033-019-0402-2

Effect of RANS Turbulence Model on Aerodynamic Behavior of Trains in Crosswind.

Tian Li • Deng Qin • Jiye Zhang

Abstract: The numerical simulation based on Reynolds time-averaged equation is one of the approved methods to evaluate the aerodynamic performance of trains in crosswind. However, there are several turbulence models, trains may present different aerodynamic performances in crosswind using different turbulence models. In order to select the most suitable turbulence model, the inter-city express 2 (ICE2) model is chosen as a research object, 6 different turbulence models are used to simulate the flow characteristics, surface pressure and aerodynamic forces of the train in crosswind, respectively. 6 turbulence models are the standard k-ε, Renormalization Group (RNG) k-ε, Realizable k-ε, Shear Stress Transport (SST) k-ω, standard k-ω and Spalart-Allmaras (SPA), respectively. The numerical results and the wind tunnel experimental data are compared. The results show that the most accurate model for predicting the surface pressure of the train is SST k-ω, followed by Realizable k-ε. Compared with the experimental result, the error of the side force coefficient obtained by SST k-ω and Realizable k-ε turbulence model is less than 1 %. The most accurate prediction for the lift force coefficient is achieved by SST k-ω, followed by RNG k-ε. By comparing 6 different turbulence models, the SST k-ω model is most suitable for the numerical simulation of the aerodynamic behavior of trains in crosswind.



(2019)32:88
DOI: 10.1186/s10033-019-0399-6

Train Vehicle Structure Design from the Perspective of Evacuation.

Hanzhao Qiu • Weining Fang

Abstract: The safety of trains, a highly efficient mode of transportation, has attracted significant attention. In the vehicle structure design of a train, the evaluation of the passenger evacuation time is necessary. The establishment of a simulation model is the fastest, most convenient, and practical way to achieve this goal. However, few scholars have focused on the reliability of a passenger train evacuation simulation model. This paper proposes a new validation method based on dynamic time warping and multidimensional scaling. The proposed method validates the dynamic process of a simulation model, provides statistical results, and can be used for small-sample scenarios such as a train evacuation scenario. The results of a case study indicate that the proposed method is an effective and quantitative approach to the validation of simulation models in a dynamic process. Thus, this paper describes the influence of the train structure size on an evacuation based on the results of simulation experiments. The structural size factors include the door width, aisle width, and seat pitch. The experiment results indicate that a wide aisle and reasonable seat pitch can promote a proper evacuation. In addition, a normal train door width has no effect on an evacuation.

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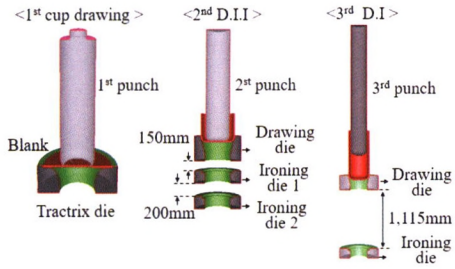

(2019)32:83
DOI: 10.1186/s10033-019-0396-9

Integrated Design of D.D.I., Filament Winding and Curing Processes for Manufacturing the High Pressure Vessel (Type II).

Hyoseo Kwak • Gunyoung Park • Hansaem Seong• Chul Kim

Abstract: As energy crisis and environment pollution all around the world threaten the widespread use of fossil fuels, compressed natural gas (CNG) vehicles are explored as an alternative to the conventional gasoline powered vehicles. Because of the limited space available for the car, the composite pressure vessel (Type II) has been applied to the CNG vehicles to reach large capacity and weight lightening vehicles. High pressure vessel (Type II) is composed of a composite layer and a metal liner. The metal liner is formed by the deep drawing and ironing (D.D.I.) process, which is a complex process of deep drawing and ironing. The cylinder part is reinforced by composite layer wrapped through the filament winding process and is bonded to the liner by the curing process. In this study, an integrated design method was presented by establishing the techniques for FE analysis of entire processes (D.D.I., filament winding and curing processes) to manufacture the CNG composite pressure vessel (Type II). Dimensions of the dies and the punches of the 1st (cup drawing), 2nd (redrawing-ironing 1-ironing 2) and 3rd (redrawing-ironing) stages were calculated theoretically, and shape of tractrix die to be satisfied with the minimum forming load was suggested for life improvement and manufacturing costs in the D.D.I. process. Thickness of the composite material was determined in the filament winding process, finally, conditions of the curing process (number of heating stage, curing temperature, heating rate and time) were proposed to reinforce adhesive strength between the composite layers.

CHINESE JOURNAL OF MECHANICAL ENGINEERING

中国机械工程学报

(Bimonthly, Started in 1988)

Vol. 32, October 2019

Supervised by China Association for Science and Technology

Sponsored by Chinese Mechanical Engineering Society

Associated to IFToMM

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

Printed by Beijing BOHS Colour Printing Co., Ltd.

Subscriptions in China Post offices throughout China
Postal Code: 2-377
Subscription Price in China: ¥ 100

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

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ISSN 1000-9345