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Chassis Coordinated Control for Full X-by-Wire Vehicles-A Review

Lei Zhang, Zhiqiang Zhang, Zhenpo Wang, Junjun Deng and David G. Dorrell

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Review

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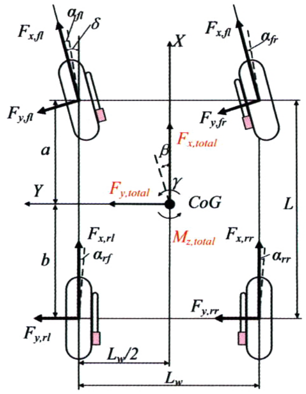
Chassis Coordinated Control for Full X-by-Wire Vehicles-A Review

Lei Zhang • Zhiqiang Zhang • Zhenpo Wang • Junjun Deng • David G. Dorrell

Abstract: An X-by-wire chassis can improve the kinematic characteristics of human-vehicle closed-loop system and thus active safety especially under emergency scenarios via enabling chassis coordinated control. This paper aims to provide a complete and systematic survey on chassis coordinated control methods for full X-by-wire vehicles, with the primary goal of summarizing recent reserch advancements and stimulating innovative thoughts. Driving condition identification including driver's operation intention, critical vehicle states and road adhesion condition and integrated control of X-by-wire chassis subsystems constitute the main framework of a chassis coordinated control scheme. Under steering and braking maneuvers, different driving condition identification methods are described in this paper. These are the trigger conditions and the basis for the implementation of chassis coordinated control. For the vehicles equipped with steering-by-wire, braking-by-wire and/or wire-controlled-suspension systems, state-of-the-art chassis coordinated control methods are reviewed including the coordination of any two or three chassis subsystems. Finally, the development trends are discussed.



(2021)34:32

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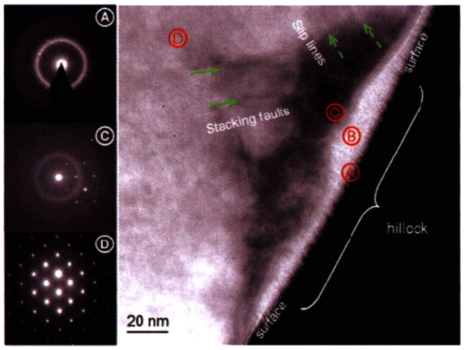
Friction-Induced Nanofabrication: A Review

Bingjun Yu • Linmao Qian

Abstract: As the bridge between basic principles and applications of nanotechnology, nanofabrication methods play significant role in supporting the development of nanoscale science and engineering, which is changing and improving the production and lifestyle of the human. Photo lithography and other alternative technologies, such as nanoimprinting, electron beam lithography, focused ion beam cutting, and scanning probe lithography, have brought great progress of semiconductor industry, IC manufacturing and micro/ nanoelectromechanical system (MEMS/NEMS) devices. However, there remains a lot of challenges, relating to the resolution, cost, speed, and so on, in realizing high-quality products with further development of nanotechnology. None of the existing techniques can satisfy all the needs in nanoscience and nanotechnology at the same time, and it is essential to explore new nanofabrication methods. As a newly developed scanning probe microscope (SPM)-based lithography, friction-induced nanofabrication provides opportunities for maskless, flexible, low-damage, low-cost and environment-friendly processing on a wide variety of materials, including silicon, quartz, glass surfaces, and so on. It has been proved that this fabrication route provides with a broad application prospect in the fabrication of nanoimprint templates, microfluidic devices, and micro/nano optical structures. This paper hereby involved the principals and operations of friction-induced nanofabrication, including friction-induced selective etching, and the applications were reviewed as well for looking ahead at opportunities and challenges with nanotechnology development. The present review will not only enrich the knowledge in nanotribology, but also plays a positive role in promoting SPM-based nanofabrication.



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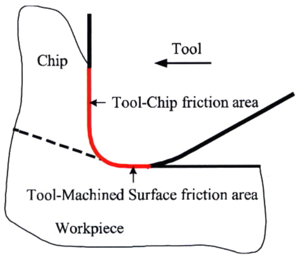

(2021)34:34
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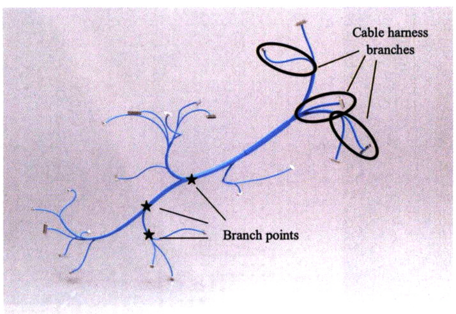
Chip Formation Mechanism of Inconel 718: A Review of Models and Approaches

Chun Liu • Min Wan • Weihong Zhang • Yun Yang

Abstract: Inconel 718, a nickel, chrome and iron alloy, has special advantages, such as high-temperature strength, thermal resistance and corrosion resistance, which facilitate wide usage in the aerospace industry, especially in the hot sections of gas turbine engines. However, machining this alloy is correlated closely with the material's inherent properties such as excellent combination of strength, hardness and toughness, low thermal conductivity and the tendency to adhere to cutting tools. This nickel alloy also contains inclusions of hard abrasive carbide particles that lead to work-hardening of the workpiece material and thus abrasive wear of the cutting tool. That is, the machining of Inconel 718 is always influenced by high mechanical and thermal loads. This article reviews the chip formation mechanism of Inconel 718. One of the main characteristics in machining of Inconel 718 is that it will produce serrated or segmented chips in a wide range of cutting speeds and feeds. Existing studies show that the chip serration or segmentation by shear localization affects the machined surface integrity, and also contributes to the chip's evacuation and the automation of machining operations. Thus, research conclusion indicates that the serrated or segmented chip phenomenon is desirable in reducing the level of cutting force, and detailed analysis of models and approaches to understand the chip formation mechanism of Inconel 718 is vital for machining this alloy effectively and efficiently. Therefore, this article presents some summaries on the models and approaches on the chip formation in machining of Inconel 718.

Intelligent Manufacturing Technology



(2021)34:33
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Multi-Branch Cable Harness Layout Design Based on Genetic Algorithm with Probabilistic Roadmap Method

Yingfeng Zhao • Jianhua Liu • Jiangtao Ma • Linlin Wu

Abstract: Current studies on cable harness layouts have mainly focused on cable harness route planning. However, the topological structure of a cable harness is also extremely complex, and the branch structure of the cable harness can affect the route of the cable harness layout. The topological structure design of the cable harness is a key to such a layout. In this paper, a novel multi-branch cable harness layout design method is presented, which unites the probabilistic roadmap method (PRM) and the genetic algorithm. First, the engineering constraints of the cable harness layout are presented. An obstacle-based PRM used to construct non-interference and near to the surface roadmap is then described. In addition, a new genetic algorithm is proposed, and the algorithm structure of which is redesigned. In addition, the operation probability formula related to fitness is proposed to promote the efficiency of the branch structure design of the cable harness. A prototype system of a cable harness layout design was developed based on the method described in this study, and the method is applied to two scenarios to verify that a quality cable harness layout can be efficiently obtained using the proposed method. In summary, the cable harness layout design method described in this study can be used to quickly design a reasonable topological structure of a cable harness and to search for the corresponding routes of such a harness.

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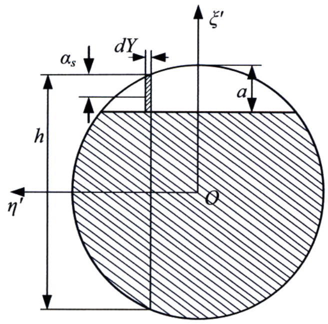
Dynamic Characteristics of Rotor System with a Slant Crack Based on Fractional Damping

Zhinong Li • Yunlong Li • Dong Wang • Zhike Peng • Haifeng Wang

Abstract: The traditional modeling method of rotor system with a slant crack considers only integer-order calculus. However, the model of rotor system based on integer-order calculus can merely describe local characteristics, not historical dependent process. The occur of fractional order calculus just makes up for the deficiency in integer-order calculus. Therefore, a new dynamic model with a slant crack based on fractional damping is proposed. Here, the stiffness of rotor system with a slant crack is solved by zero stress intensity factor method. The proposed model is simulated by Runge-Kutta method and continued fraction Euler method. The influence of the fractional order, rotating speed, and crack depth on the dynamic characteristics of rotor system is discussed. The simulation results show that the amplitude of torsional excitation frequency increases significantly with the increase of the fractional order. With the increase of the rotating speed, the amplitude of first harmonic component becomes gradually larger, the amplitude of the second harmonic becomes smaller, while the amplitude of the other frequency components is almost invariant. The shaft orbit changes gradually from an internal 8-type shape to an ellipse-type shape without overlapping. With the increase of the slant crack depth, the amplitude of the transverse response frequency in the rotor system with a slant crack increases, and the amplitude in the second harmonic component also increases significantly. In addition, the torsional excitation frequency and other coupling frequency components also occur. The proposed model is further verified by the experiment. The valuable conclusion can provide an important guideline for the fault diagnosis of rotor system with a slant crack.

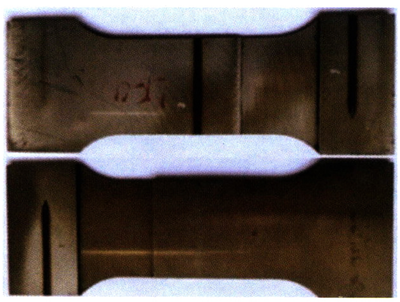


(2021)34:39
DOI: 10.1186/s10033-021-00557-4

Fatigue Resistance and Failure Behavior of Penetration and Non-Penetration Laser Welded Lap Joints

Xiangzhong Guo • Wei Liu • Xiqing Li • Haowen Shi • Zhikun Song

Abstract: Penetration and non-penetration lap laser welding is the joining method for assembling side facade panels of railway passenger cars, while their fatigue performances and the difference between them are not completely understood. In this study, the fatigue resistance and failure behavior of penetration 1.5+0.8-P and non-penetration 0.8+1.5-N laser welded lap joints prepared with 0.8 mm and 1.5 mm cold-rolled 301L plates were investigated. The weld beads showed a solidification microstructure of primary ferrite with good thermal cracking resistance, and their hardness was lower than that of the plates. The 1.5+0.8-P joint exhibited better fatigue resistance to low stress amplitudes, whereas the 0.8+1.5-N joint showed greater resistance to high stress amplitudes. The failure modes of 0.8+1.5-N and 1.5+0.8-P joints were 1.5 mm and 0.8 mm lower lap plate fracture, respectively, and the primary cracks were initiated at welding fusion lines on the lap surface. There were long plastic ribs on the penetration plate fracture, but not on the non-penetration plate fracture. The fatigue resistance stresses in the crack initiation area of the penetration and non-penetration plates calculated based on the mean fatigue limits are 408 MPa and 326 MPa, respectively, which can be used as reference stress for the fatigue design of the laser welded structures. The main reason for the difference in fatigue performance between the two laser welded joints was that the asymmetrical heating in the non-penetration plate thickness resulted in higher residual stress near the welding fusion line.



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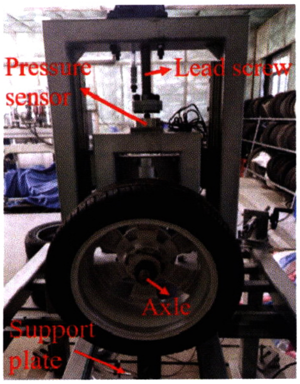
Advanced Transportation Equipment



(2021)34:6
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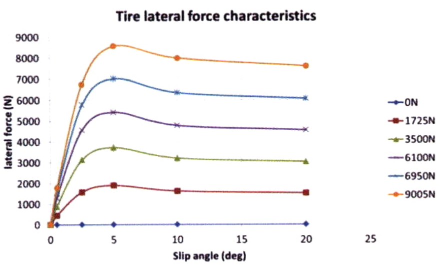
Aerodynamic Characteristics of Isolated Loaded Tires with Different Tread Patterns: Experiment and Simulation

Haichao Zhou • Zhen Jiang • Guolin Wang • Shupei Zhang

Abstract: The current research of tire aerodynamics mainly focus on the isolated and simplified tread tire. Compared with the real complex pattern tire, the tread pattern structure and deformed profile of a loaded tire has a greatly influence on tire aerodynamic drag. However, the mechanisms of the isolated loaded tires with different tread patterns effects on the aerodynamic drag are subjects worthy of discussion. The purpose of this study is to experimentally and computationally investigate the aerodynamic characteristics of three tires 185/65 R14 with different patterns under loaded. A wind tunnel test model was first established using three-dimensional (3D) printing with a ratio of 1:1, and the pressure coefficients C_p of the three tires with different patterns are measured. The paper then conducted computational fluid dynamics (CFD) simulations for analyzing the pressure and flow characteristics. The accuracy of CFD simulation is verified by comparing the simulation results with the test results of pressure coefficients C_p, and they are of good consistency. While, the general analysis of pressure coefficients C_p results of the three tires indicates high-pressure area on the windward surface, and occurrence of low-pressure area on the leeward surface, the pressure coefficients C_p of all three tires decreased firstly and then increased along in the air flow direction. The authors finally analyzed the effect of tread patterns on the flow field around the tire and revealed the differences between flow characteristics and aerodynamic drag. The results show that, angle of tire lateral groove has great effect on the flow field characteristics such that; the more the angle of lateral groove agrees with the air flow direction, the less the flow separation and flow vortices, and a minimum observable aerodynamic drag. The research provides a guidance for the design of low aerodynamic drag tires, and helps to illustrate the impact of tire aerodynamics on the car body in the future.



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Research on Key Issues of Consistency Analysis of Vehicle Steering Characteristics

Yanhua Liu • Xin Guan • Pingping Lu • Rui Guo

Abstract: Given the global lack of effective analysis methods for the impact of design parameter tolerance on performance deviation in the vehicle proof-of-concept stage, it is difficult to decompose performance tolerance to design parameter tolerance. This study proposes a set of consistency analysis methods for vehicle steering performance. The process of consistency analysis and control of automotive performance in the conceptual design phase is proposed for the first time. A vehicle dynamics model is constructed, and the multi-objective optimization software Isight is used to optimize the steering performance of the car. Sensitivity analysis is used to optimize the design performance value. The tolerance interval of the performance is obtained by comparing the original car performance value with the optimized value. With the help of layer-by-layer decomposition theory and interval mathematics, automotive performance tolerance has been decomposed into design parameter tolerance. Through simulation and real vehicle experiments, the validity of the consistency analysis and control method presented in this paper are verified. The decomposition from parameter tolerance to performance tolerance can be achieved at the conceptual design stage.

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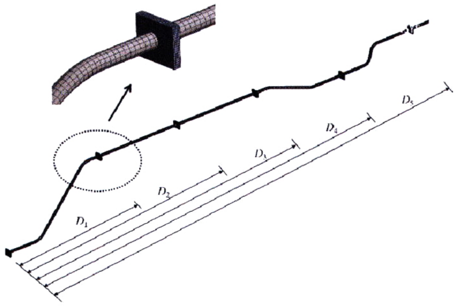
Experimental Investigation and Optimization Design of Multi-Support Pipeline System

Xiantao Zhang • Wei Liu • Yamei Zhang • Yujie Zhao

Abstract: The design of aircraft hydraulic pipeline system is limited by many factors, such as the integrity of aviation structure or narrow installation space, so the limited clamp support position should be considered. This paper studied the frequency adjustment and dynamic responses reduction of the multi-support pipeline system through experiment and numerical simulation. To avoid the resonance of pipeline system, we proposed two different optimization programs, one was to avoid aero-engine working range, and another was to avoid aircraft hydraulic pump pulsation range. An optimization method was introduced in this paper to obtain the optimal clamp position. The experiments were introduced to validate the optimization results, and the theoretical optimization results can agree well with the test. With regard to avoiding the aero-engine vibration frequency, the test results revealed that the first natural frequency was far from the aero-engine vibration frequency. And the dynamic frequency sweep results showed that no resonance occurred on the pipeline in the engine vibration frequency range after optimization. Additionally, with regard to avoiding the pump vibration frequency, the test results revealed that natural frequencies have been adjusted and far from the pump vibration frequency. And the dynamic frequency sweep results showed that pipeline under optimal clamp position cannot lead to resonance. The sensitivity analysis results revealed the changing relationships between different clamp position and natural frequency. This study can provide helpful guidance on the analysis and design of practical aircraft pipeline.



(2021)34:1
DOI: 10.1186/s10033-020-00524-5

Aerodynamic-Parameter Identification and Attitude Control of Quad-Rotor Model with CIFER and Adaptive LADRC

Sen Yang • Leiping Xi • Jiaxing Hao • Wenjie Wang

Abstract: Current research on quadrotor modeling mainly focuses on theoretical analysis methods and experimental methods, which have problems such as weak adaptability to the environment, high test costs, and long durations. Additionally, the PID controller, which is currently widely used in quadrotors, requires improvement in anti-interference. Therefore, the aforementioned research has considerable practical significance for the modeling and controller design of quadrotors with strong coupling and nonlinear characteristics. In the present research, an aerodynamic-parameter estimation method and an adaptive attitude control method based on the linear active disturbance rejection controller (LADRC) are designed separately. First, the motion model, dynamics model, and control allocation model of the quad-rotor are established according to the aerodynamic theory and Newton–Euler equations. Next, a more accurate attitude model of the quad-rotor is obtained by using a tool called CIFER to identify the aerodynamic parameters with large uncertainties in the frequency domain. Then, an adaptive attitude decoupling controller based on the LADRC is designed to solve the problem of the poor anti-interference ability of the quad-rotor and adjust the key control parameter b_0 automatically according to the change in the moment of inertia in real time. Finally, the proposed approach is verified on a semi-physical simulation platform, and it increases the tracking speed and accuracy of the controller, as well as the anti-disturbance performance and robustness of the control system. This paper proposes an effective aerodynamic-parameter identification method using CIFER and an adaptive attitude decoupling controller with a sufficient anti-interference ability.

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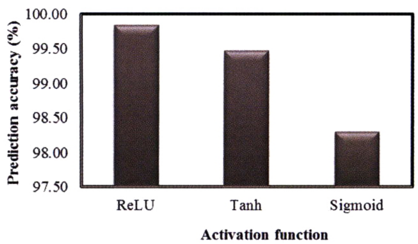
Cylinder Pressure Prediction of An HCCI Engine Using Deep Learning

Halit Yaşar • Gültekin Çağıl • Orhan Torkul • Merve Şişci



Abstract: Engine tests are both costly and time consuming in developing a new internal combustion engine. Therefore, it is of great importance to predict engine characteristics with high accuracy using artificial intelligence. Thus, it is possible to reduce engine testing costs and speed up the engine development process. Deep Learning is an effective artificial intelligence method that shows high performance in many research areas through its ability to learn highlevel hidden features in data samples. The present paper describes a method to predict the cylinder pressure of a Homogeneous Charge Compression Ignition (HCCI) engine for various excess air coefficients by using Deep Neural Network, which is one of the Deep Learning methods and is based on the Artificial Neural Network (ANN). The Deep Learning results were compared with the ANN and experimental results. The results show that the difference between experimental and the Deep Neural Network (DNN) results were less than 1%. The best results were obtained by Deep Learning method. The cylinder pressure was predicted with a maximum accuracy of 97.83% of the experimental value by using ANN. On the other hand, the accuracy value was increased up to 99.84% using DNN. These results show that the DNN method can be used effectively to predict cylinder pressures of internal combustion engines.

Smart Materials

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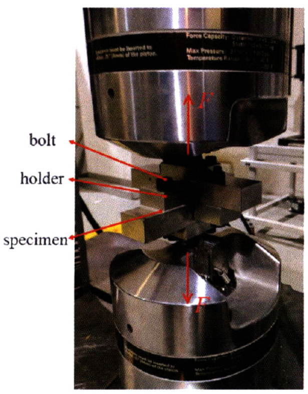
Prediction of Cross-Tension Strength of Self-Piercing Riveted Joints Using Finite Element Simulation and XGBoost Algorithm

Jianping Lin • Chengwei Qi • Hailang Wan • Junying Min • Jiajie Chen • Kai Zhang • Li Zhang



Abstract: Self-piercing riveting (SPR) has been widely used in automobile industry, and the strength prediction of SPR joints always attracts the attention of researchers. In this work, a prediction method of the cross-tension strength of SPR joints was proposed on the basis of finite element (FE) simulation and extreme gradient boosting decision tree (XGBoost) algorithm. An FE model of SPR process was established to simulate the plastic deformations of rivet and substrate materials and verified in terms of cross-sectional dimensions of SPR joints. The residual mechanical field from SPR process simulation was imported into a 2D FE model for the cross-tension testing simulation of SPR joints, and cross-tension strengths from FE simulation show a good consistence with the experiment result. Based on the verified FE model, the mechanical properties and thickness of substrate materials were varied and then used for FE simulation to obtain cross-tension strengths of a number of SPR joints, which were used to train the regression model based on the XGBoost algorithm in order to achieve prediction for cross-tension strength of SPR joints. Results show that the cross-tension strengths of SPR steel/aluminum joints could be successfully predicted by the XGBoost regression model with a respective error less than 7.6% compared to experimental values.

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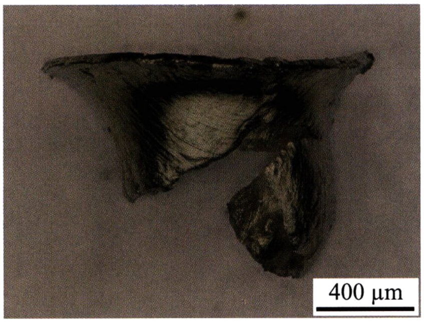
Experimental Investigation on Micro Deep Drawing of Stainless Steel Foils with Different Microstructural Characteristics

Jingwei Zhao • Tao Wang • Fanghui Jia • Zhou Li • Cunlong Zhou • Qingxue Huang • Zhengyi Jiang

Abstract: In the present work, austenitic stainless steel (ASS) 304 foils with a thickness of 50 μm were first annealed at temperatures ranging from 700 to 1100 ℃ for 1 h to obtain different microstructural characteristics. Then the effects of microstructural characteristics on the formability of ASS 304 foils and the quality of drawn cups using micro deep drawing (MDD) were studied, and the mechanism involved was discussed. The results show that the as-received ASS 304 foil has a poor formability and cannot be used to form a cup using MDD. Serious wrinkling problem occurs on the drawn cup, and the height profile distribution on the mouth and the symmetry of the drawn cup is quite non-uniform when the annealing temperature is 700 ℃. At annealing temperatures of 900 and 950 ℃, the drawn cups are both characterized with very few wrinkles, and the distribution of height profile, symmetry and mouth thickness are uniform on the mouths of the drawn cups. The wrinkling becomes increasingly significant with a further increase of annealing temperature from 950 to 1100 ℃. The optimal annealing temperatures obtained in this study are 900 and 950 ℃ for reducing the generation of wrinkling, and therefore improving the quality of drawn cups. With non-optimized microstructure, the distribution of the compressive stress in the circumferential direction of the drawn foils becomes inhomogeneous, which is thought to be the cause of the occurrence of localized deformation till wrinkling during MDD.



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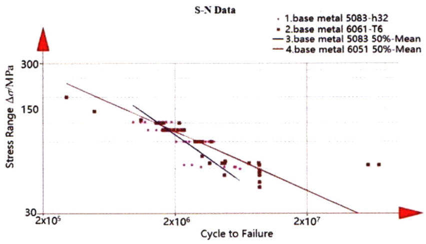
Unified Principal S-N Equation for Friction Stir Welding of 5083 and 6061 Aluminum Alloys

Xiangwei Li • Ji Fang • Xiaoli Guan

Abstract: With the popularization of friction stir welding (FSW), 5083-H321 and 6061-T6 aluminum alloy materials are widely used during the FSW process. In this study, the fatigue life of friction stir welding with two materials, i.e., 5083-H321 and 6061-T6 aluminum alloy, are studied. Fatigue tests were carried out on the base metal of these two materials as well as on the butt joints and overlapping FSW samples. The principle of the equivalent structural stress method is used to analyze the FSW test data of these two materials. The fatigue resistances of these two materials were compared and a unified principal S–N curve equation was fitted. Two key parameters of the unified principal S–N curve obtained by fitting, C_d is 4222.5, and h is 0.2693. A new method for an FSW fatigue life assessment was developed in this study and can be used to calculate the fatigue life of different welding forms with a single S–N curve. Two main fatigue tests of bending and tension were used to verify the unified principal S–N curve equation. The results show that the fatigue life calculated by the unified mean 50% master S–N curve parameters are the closest to the fatigue test results. The reliability, practicability, and generality of the master S–N curve fitting parameters were verified using the test data. The unified principal S–N curve acquired in this study can not only be used in aluminum alloy materials but can also be applied to other materials.



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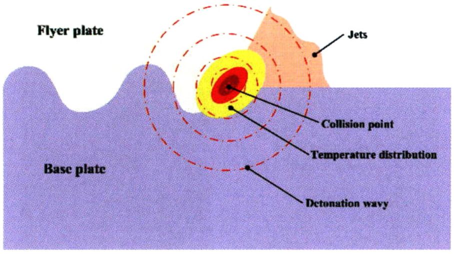
Interfacial Morphology and Bonding Mechanism of Explosive Weld Joints

Tingting Zhang • Wenxian Wang • Zhifeng Yan • Jie Zhang



Abstract: Interfacial structure greatly affects the mechanical properties of laminated plates. However, the critical material properties that impact the interfacial morphology, appearance, and associated bonding mechanism of explosive welded plates are still unknown. In this paper, the same base plate (AZ31B alloy) and different flyer metals (aluminum alloy, copper, and stainless steel) were used to investigate interfacial morphology and structure. SEM and TEM results showed that typical sine wave, wave-like, and half-wave-like interfaces were found at the bonding interfaces of Al/Mg, Cu/Mg and SS/Mg clad plates, respectively. The different interfacial morphologies were mainly due to the differences in hardness and yield strength between the flyer and base metals. The results of the microstructural distribution at the bonding interface indicated metallurgical bonding, instead of the commonly believed solid-state bonding, in the explosive welded clad plate. In addition, the shear strength of the bonding interface of the explosive welded Al/Mg, Cu/Mg and SS/Mg clad plates can reach up to 201.2 MPa, 147.8 MPa, and 128.4 MPa, respectively. The proposed research provides the design basis for laminated composite metal plates fabrication by explosive welding technology.

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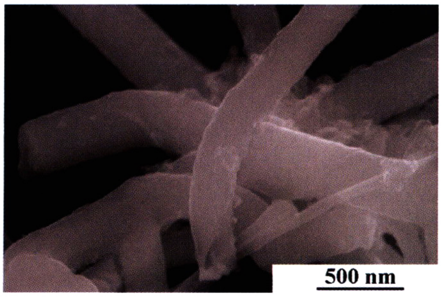
Fabrication of Carbon Nanotubes and Rare Earth Pr Reinforced AZ91 Composites by Powder Metallurgy

Ning Li • Hong Yan • Qingjie Wu • Zeyu Cao



Abstract: It can be known from a large number of research results that improving the dispersibility of CNTs can effectively optimize the mechanical properties of the corresponding metal matrix composites. However, the crucial issue of increasing the bonding of CNTs and the matrix is still unsolved. In this paper, a novel method was developed to increase interfacial bonding strength by coating titanium oxide (TiO_2) on the surface of CNTs. The rare earth Pr and TiO_2@CNTs-reinforced AZ91matrix composites were successfully fabricated by powder metallurgy. Hot press sintering and hot extrusion of the milled powder was performed. After hot extrusion, the influence of TiO_2@CNTs on the microstructure and mechanical properties of the composites were investigated. The results showed that the coating process can improve the distribution of CNTs in Mg alloy. The CNTs refined the grains of the matrix, and the CNTs were presented throughout the extrusion direction. When the TiO_2@CNTs content was 1.0 wt. %, the yield strength (YS), ultimate tensile strength (UTS), and elongation of the alloy attained maximum values. The values were improved by 23.5 %, 82.1 %, and 40.0 %, respectively, when compared with the AZ91 alloy. Good interfacial bonding was achieved, which resulted in an effective tensile loading transfer at the interface. CNTs carried the tensile stress and were observed on the tensile fracture.

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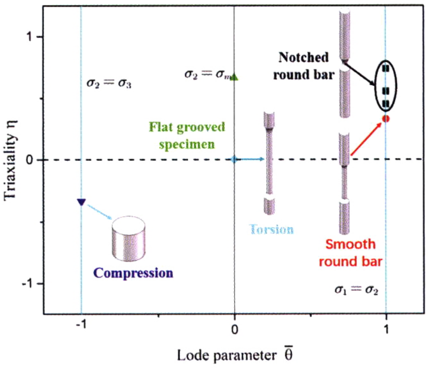
DOI: 10.1186/s10033-021-00549-4

Comparison of Modified Mohr–Coulomb Model and Bai–Wierzbicki Model for Constructing 3D Ductile Fracture Envelope of AA6063

Jianye Gao • Tao He • Yuanming Huo • Miao Song • Tingting Yao • Wanbo Yang

Abstract: Ductile fracture of metal often occurs in the plastic forming process of parts. The establishment of ductile fracture criterion can effectively guide the selection of process parameters and avoid ductile fracture of parts during machining. The 3D ductile fracture envelope of AA6063-T6 was developed to predict and prevent its fracture. Smooth round bar tension tests were performed to characterize the flow stress, and a series of experiments were conducted to characterize the ductile fracture firstly, such as notched round bar tension tests, compression tests and torsion tests. These tests cover a wide range of stress triaxiality (ST) and Lode parameter (LP) to calibrate the ductile fracture criterion. Plasticity modeling was performed, and the predicted results were compared with corresponding experimental data to verify the plasticity model after these experiments. Then the relationship between ductile fracture strain and ST with LP was constructed using the modified Mohr–Coulomb (MMC) model and Bai-Wierzbicki (BW) model to develop the 3D ductile fracture envelope. Finally, two ductile damage models were proposed based on the 3D fracture envelope of AA6063. Through the comparison of the two models, it was found that BW model had better fitting effect, and the sum of squares of residual error of BW model was 0.9901. The two models had relatively large errors in predicting the fracture strain of SRB tensile test and torsion test, but both of the predicting error of both two models were within the acceptable range of 15%. In the process of finite element simulation, the evolution process of ductile fracture can be well simulated by the two models. However, BW model can predict the location of fracture more accurately than MMC model.



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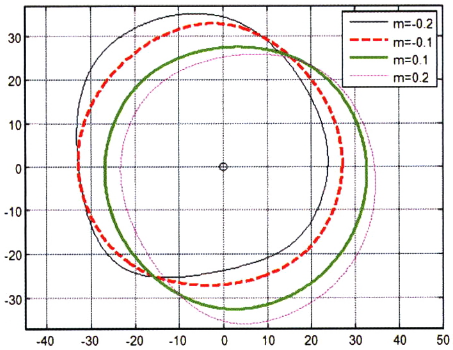
Research and Test of Three-Pulley Noncircular Synchronous Pulley Transmission Mechanism with Minimum Slack

Jianneng Chen • Xincheng Sun • Chuanyu Wu • Dadu Xiao • Jun Ye

Abstract: The noncircular synchronous belt drive mechanism has demonstrated certain achievements and has been used in special fields. Research regarding noncircular synchronous belt drive mechanisms has focused on optimization design and kinematic analysis in China, whereas two pulley noncircular synchronous belt transmissions have been developed overseas. However, owing to the noncircular characteristics of the belt pulley, the real-time variation in the belt length slack during the transmission of the noncircular synchronous belt is significant, resulting in high probabilities of skipping and vibration. In this study, a noncircular tensioning pulley is added to create a stable three-pulley noncircular synchronous belt driving mechanism and a good synchronous belt tensioning, with no skipping; hence, the non-uniform output characteristic of the driven pulley is consistent with the theoretical value. In the circular noncircular noncircular three-pulley noncircular synchronous belt mechanism, the pitch curve of the driving synchronous belt pulley is circular, whereas those of the driven synchronous belt and tensioning pulleys are noncircular. To minimize the slack of the belt length of the synchronous belt and the constraint of the concavity and circumference of the tensioning pulley, an automatic optimization model of the tensioning pulley pitch curve is established. The motion simulation, analysis, and optimization code for a three-belt-pulley noncircular synchronous belt drive mechanism is written, and the variation in belt length slack under different speed ratios is analyzed based on several examples. The testbed for a circular–noncircular–noncircular three-pulley noncircular synchronous belt transmission mechanism is developed. The test shows that the three-pulley noncircular synchronous belt drives well. This study proposes an automatic optimization algorithm for the tensioning pulley pitch curve of a noncircular synchronous belt transmission mechanism; it yields a stable transmission of the noncircular synchronous belt transmission mechanism as well as non-uniform output characteristics.



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