Critical depth and damage mechanism of nanoscale cutting graphene on silicon substrate

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Keywords: Graphene, damage, mechanism, nano cutting, silicon

Graphene possesses excellent mechanical, electrical, optical, thermal, and other physical properties, and it is widely used in conductive films, energy-storage devices, field effect transistor, biosensor and quantum chip. However, the characteristics of graphene without a band gap limit its use in logic applications. Therefore, opening the band gap is very crucial for graphene. Many methods including applying an electric field, applying stress, chemical doping, constructing graphene nanonets and graphene nanoribbons (GNRs) are developed to open the gap of graphene. Among them, nano cutting is a low-cost, efficient and controllable method to obtain the GNRs. So the presented study investigates the critical depth and damage mechanism of nanoscale cutting graphene on silicon substrates and analyzes the influences of cutting process on edge structure by using the method of molecular dynamics. The theoretical analysis results reveal that the substrates can increase the load capacity of graphene film. The critical cutting load increased by 52% and the crucial depth decreases by 36% in comparison with the graphene without substrate. Furthermore, the silicon substrate undergoes plastic deformation and elastic deformation during nano cutting process. Amorphous silicon atoms were found at the bottom of the probe tip. Carbon chain, carbon ring, cracks, atom packing are the typical defects of nanocutting. When the depth of nano cutting is about critical depth, the cutting quality of grapene is best.

Experimental study on high efficient and precision internal grinding of silicon nitride ceramic thin-wall bearing ring

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Keywords: Grinding, Silicon Nitride, Surface roughness, Thin-wall bearing, grinding efficiency

The research aims to achieve high efficient and precision in longitudinal grinding of silicon nitride ceramic thin-wall bearing rings, solve issues such as challenging machining, low efficiency and poor grinding surface integrity during the grinding process. Analyzing the impact of various clamping methods on the grinding surface integrity of thin-wall bearing rings. The research determines the variation principle of the maximum undeformed chip thickness during transverse feed and the trajectory of abrasive particles during longitudinal feed of the grinding wheel. Surface roughness (SR) and material removal rate (MRR) during internal grinding of the bearing rings serve as the primary evaluation metrics. Utilizing a combination of single-factor and orthogonal experiments to analyze the impact of grinding parameters and optimize machining parameters. The research finds that the spring chuck exhibits characteristics of minimal clamping strain and uniform stress distribution, contributing significantly to enhancing the grinding surface integrity of thin-wall bearing rings. The comprehensive influence order of high efficiency and precision internal grinding of silicon nitride ceramic thin-wall bearing rings is the grinding wheel speed, transverse cutting depth, axial oscillation distance, transverse feed rate, and axial oscillation rate. Optimal grinding parameters are grinding wheel speed of 6000 rpm, transverse cutting depth of 15μm, transverse feed rate of 30μm/min, axial oscillation distance of 6mm and axial oscillation rate of 100mm/min. Uniform clamping of the bearing rings and increase of grinding wheel speed are main factors for enhancing the comprehensive grinding performance of internal grinding of silicon nitride ceramic thin-wall bearing rings. Transverse and axial feed parameters of the grinding wheel exhibit a negative correlation with surface roughness and material removal rate. The design of grinding parameters in this research facilitates efficient and precise grinding of bearing rings.

High temperature tribological behavior of nickel-base superalloy with addition of recycled superalloy

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Keywords: Tribology, film, high temperature, recycling alloy, superalloy

The recycling of superalloy scraps is of significance for cost-efficiency and green manufacturing. The effect of adding 60% recycled alloy in the processes of vacuum induction melting is investigated on microstructure, mechanical properties and tribological behaviors, using OM, SEN-EDS, tensile test and tribometer in this study. It is shown that the recycled alloy promotes the refinement of microstructure and precipitation of γ′ phase, however reduces the tensile strength and ductility at room and high temperatures due to the introduction of impurities. At 300℃, the superalloy with 60% revert shows less wear rate and coefficient of friction (COF) due to the increased hardness compared to the newly produced superalloy without revert. Furthermore, a notable decrease in both the COF and wear rate is observed as the temperature increases from 300°C to 730°C. This result is related to the formation of a dense oxide film on the frictional interface at 730°C, which serves to lubricate and protect the surface. The thin film and the subsurface microstructure are characterized, which shows the presence of re-crystallization phases at high temperature. The observation of wear debris also validates the change of wear form at different temperatures. These findings are of importance for understanding the high-temperature behaviors of superalloy and the optimization of alloy utilization/recycling.

Intelligent Recognition Algorithm for Cutting Load State Based on DBSCAN Algorithm

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Keywords: Cutting force; Load characteristics; Intelligent recognition; Clustering algorithm; Density law; Agent

An algorithm for intelligent recognition of cutting force state in cutting process is presented in this paper. This method uses density clustering algorithm to establish cluster classification algorithm, takes distance measure as cluster classification criterion, takes core point of cluster as cutting load learning object, and makes judgment by cutting load ideal value to realize intelligent recognition of cutting load characteristics. In this paper, the algorithm and Agent technology are used to intelligently identify and visualize the cutting force load under the condition of high speed stone milling. The research shows that the algorithm can realize the intelligent recognition and judgment of cutting state, and lays a theoretical foundation for the intelligent optimization of cutting parameters.

Laser-induced layer-by-layer removal and thermo-mechanical action mechanisms of FeCo-based multilayer wave-absorbing coatings

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Keywords: Laser-induced removal; Layer-by-layer removal; Thermo-mechanical action mechanisms; FeCo-based wave-absorbing coatings; Macrodynamic removal behavior; Microscopic motion models

The excellent performance of laser-induced removal has been widely recognized, yet the limitation of its applications has been gradually approached for complex multilayer coatings in practical situations. Therefore, it is necessary to clarify the laser-induced removal mechanisms of different material layers, which may contribute to guide precise and controllable layer-by-layer removal and subsequent repair. Herein, the laser-induced layer-by-layer removal of FeCo-based multilayer wave-absorbing coatings was designed and verified. The macro/micro morphologies and elemental analysis indicated that the removal of topcoat and wave-absorbing layer was dominated by thermal ablation. Interestingly, experiments and simulations demonstrated that a shift in the removal mechanism, *i.e.*, from the ablation mechanism to the stripping mechanism, occurred when the laser irradiated the primer. It is mainly attributed to the competing contributions of temperature rise and thermal stress to the removal effect. Subsequent macrodynamic behavior captured by a high-speed camera also validated the combination of the both removal mechanisms. Additionally, evolution of crystalline phase and element valence-state was revealed. Further laser-induced breakdown spectroscopy revealed the microscopic material motions during the layer-by-layer removal, including molecular bond breaking induced by multiphoton absorption, atomic ionization, excitation and compounding of electrons and ions, crystal lattice deformation caused by electron-phonon coupling, etc. Based on the above analysis, the thermo-mechanical action mechanisms and microscopic motion models of laser-induced layer-by-layer removal for FeCo-based multilayer wave-absorbing coatings were established, which is expected to be an ideal method for breaking through the limitation of laser-induced removal's applications.

Predictions of Friction and Wear in Ball Bearings Based on a 3D point Contact Mixed EHL Model

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Keywords: 3D point contact mixed EHL, Ball bearings, Sinusoidal surface roughness, Wear

Ship gas turbine bearings are subjected to heavy loads and intricate interface micro-morphologies, predominantly operate in a mixed lubrication regime. Excessive asperity relative sliding can cause wear at contact points.In this paper, a numerical solution procedure is developed for the predictions of transient friction and wear in the marine ball bearings based on the 3D point contact mixed lubrication simulation. The obtained results indicate that as the amount of bearing material removed increases, the actual area of wear marks produced is larger than the elliptical contact area. In addition, It is observed that the conditions of heavy load and low material hardness usually lead to significantly increased maximum wear depth. In the meantime, the maximum wear of the inner raceway is on both sides. In this paper, a numerical solution procedure is developed for the predictions of transient friction and wear in the marine ball bearings based on the 3D point contact mixed lubrication simulation. The obtained results indicate that as the amount of bearing material removed increases, the actual area of wear marks produced is larger than the elliptical contact area. In addition, It is observed that the conditions of heavy load and low material hardness usually lead to significantly increased maximum wear depth. In the meantime, the maximum wear of the inner raceway is on both sides.

Preparation and mechanical properties of multilayer diamond coatings on Si3N4 ceramic substrate

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Keywords: Hot Filament Chemical Vapor Deposition; Silicon nitride ceramics; Multi-layers diamond coatings; Mechanical properties

Silicon nitride (Si_3N_4) ceramic materials has become an advanced engineering ceramic material due to its high hardness, high fracture toughness, good wear resistance, good chemical and thermal stability. However, Si_3N_4 ceramic bearings have a high coefficient of friction under dry friction conditions and their surfaces may also be damaged by oxidation. In order to avoid cracking and extension-related forms of failure on Si_3N_4, a very tough and erosion-resistant coating can be used to reduce losses.In this paper, the hot filament chemical vapor deposition technique is used to deposit diamond coatings. The optimum growth conditions for diamond coatings are with a substrate temperature of 900 °C and a chamber pressure of 1 kPa. Micron crystalline columnar structures have only few radial cracks and high critical loads when subjected to impact loading because of the strong mechanical interlocking effect with the substrate. Nano diamond coatings have more grain boundaries and sp^2 carbon within the coating, with extensive exfoliation (307 μm) and low critical loads (5.73 N) when subjected to impact and the worst bonding performance to the substrate. The multi-layer structure showed stronger bonding properties than the single-layer coatings, due to the nanocrystals on the surface being used to improve the toughness and resistance to plastic deformation of the coating, and the micron crystals on the bottom layer being used to improve bonding to the substrate, critical loads and resistance to crack ductility. The gradient multilayer diamond coatings consist of the superficial nanodiamond coating with a lower surface roughness, the submicron layer with slightly larger grains than the surface layer forming a bridge layer, and the bottom layer with micron grains effectively enhancing the bonding between the coatings and substrates, hence increasing the toughness of the coatings, reducing the friction coefficient and resulting in a superior wear resistance.

Preparation and research on gradient TiN thin films on Si3N4 ceramic substrates based on PVD

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Symposium: 14. Part Surface Technology and Green Manufacturing (PST)
Keywords: TiN film, ceramic bearing, gradient film

The Si3N4 all ceramic bearing can reduce the centrifugal force and increase the speed, but the surface lubrication and lose efficacy influence the application. TiN film can be used to enhance the wear resistance and bearing lifetime. The research focus on the homogeneity and gradient TiN film grain orientation and surface and cross-sectional morphology influence on tribological performance. The film preparation on the Si3N4 substrate by PVD change the power, temperature and nitrogen concentration. The homogeneity and gradient film are prepared, the nitrogen concentration is 25sccm and 0.8sccm/5min respectively. The results indicate the gradient film is beneficial to nanocrystalline growth and frictional coefficient and wear rate reduction. Gradient TiN film has higher membrane based adhesion than homogeneity film. When the nitrogen concentration is 0.8sccm/5min, the gradient film has the best tribological performance, it can be used in all ceramic bearing field as functional film.

Research on friction and wear characteristics of full ceramic ball bearings under low temperature conditions

by Chao Wei | Shenyang Jianzhu University

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Symposium: 14. Part Surface Technology and Green Manufacturing (PST)
Keywords: HIPSN full ceramic bearing; Friction and wear□Low temperature condition□Surface quality□Lubrication characteristic

With the increasingly harsh usage conditions and environment of rolling bearings, the existing bearing steel grades can no longer meet or fully meet the requirements of the host for bearings. Especially under low temperature conditions, the solidification of lubricating oil (grease) will cause the loss of fluidity or even overall disappearance of the lubricating film structure between components, ultimately leading to increased bearing wear and failure. This article focuses on the application performance of silicon nitride all ceramic ball bearings under low temperature conditions, conducts friction and wear tests on silicon nitride ceramic materials under low temperature conditions, and explores the influence of low temperature conditions and material surface roughness on the friction and wear performance of silicon nitride. By building a friction and wear test platform for bearing components under low temperature conditions, combined with the friction and wear characteristics of silicon nitride ceramics in different temperature environments, the influence of temperature changes on the friction and wear characteristics of silicon nitride ceramics is explored, revealing the self-lubricating characteristics of silicon nitride ceramic materials under low temperature conditions. The friction and wear characteristics of GCr15 bearing steel under low temperature conditions are compared and analyzed to provide reference for verifying the advantages of friction and wear properties of silicon nitride ceramic materials under low temperature conditions and its application in bearing field.

Research on magnetic-thermal coupling modeling and simulation of motorized spindle based on digital twin

by Wang Zhan | Zhao Rui | Wang Zinan | Zhu Jintao | Zhang Ke | Shenyang Jianzhu University | Shenyang Jianzhu University | Shenyang Jianzhu University | Shenyang Jianzhu University | Shenyang University of Technology

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Keywords: Motorized spindle; Digital twin; Magneto-thermal coupling; Dynamic characteristics

In order to solve the problem that the physical model can’t be dynamically updated in real-time in the dynamic simulation of magnetic-thermal coupling of motorized spindle, a dynamic modelling method of magnetic-thermal coupling of motorized spindle based on digital twin is proposed to carry out two-way interaction between the motorized spindle twin mechanism model and the data model through the twin database and service platform constructed, and a dynamic model of magnetic-thermal coupling of motorized spindle is established based on the twin database to analyse the real-time change of temperature rise, structural deformation, and dynamic characteristics of the motorized spindle under different working conditions. By comparing with the traditional motorized spindle simulation model, the dynamic simulation results of magneto-thermal coupling of motorized spindle under twinning drive are closer to the entity. Finally, the accuracy of the model was verified by building a test rig for the motorized spindle. The research results lay a theoretical foundation for further exploring the operating state of the motorized spindle under different working conditions.

Research on Temperature Rise Characteristics of Silicon Nitride Full-ceramic Ball Bearing Grease Lubrication for High-Speed Motorized Spindle

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Symposium: 14. Part Surface Technology and Green Manufacturing (PST)
Keywords: Silicon Nitride; Full-ceramic Ball Bearings; Grease Lubrication; Grease filling quantity; Temperature rise characteristics

With the advancement of spindle technology, achieving high precision and speed has become a challenge for traditional steel bearings lubricated with grease due to their high temperature rise, excessive wear, and risk of gluing, which cannot meet the high-performance requirements of motorized spindles. On the other hand, silicon nitride ceramics are self-lubricating, wear-resistant, and lightweight, making them ideal for use in ceramic ball bearings. By using silicon nitride ceramic ball bearings, the limit speed of grease-lubricated bearings can be increased. In this study, we investigated the temperature rise characteristics of grease-lubricated full-ceramic ball bearings by creating a simulation model of grease flow and temperature field. We studied the influence of grease filling quantity on grease distribution and the impact of rotating speed on temperature field distribution. Our findings indicate that the grease filling quantity of 15%-25% ensures even grease distribution without any accumulation of grease, and the temperature of the bearing outer ring increases with the increase of rotating speed. We also found that the suitable range of grease filling quantity for grease-lubricated full-ceramic ball bearings is 0.9-1.2g. At a rotating speed of 18000r/min, the outer ring temperature of the grease-lubricated bearing is 44℃, which is within a reasonable range, providing a helpful basis for the use of grease-lubricated full-ceramic ball bearings for motorized spindles.

Research on the Friction, Lubrication and Temperature Rise Characteristics of Silicon Nitride Full Ceramic Ball Bearing at Low Temperature

by Jian Sun | Shenyang Jianzhu University

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Keywords: Friction and lubrication, Full ceramic ball bearing, Liquid nitrogen/nitrogen, Low-temperature condition, Temperature rise characteristic

In order to understand the service performance of full ceramic ball bearings under extreme working conditions and improve their service life, dynamic characteristic tests of full ceramic ball bearings under low-temperature conditions were carried out by a low-temperature bearing life testing machine. We measured temperature rise and friction under extremely low-temperature environments. A liquid nitrogen lubrication model of full ceramic ball bearings was established. The heat-flow coupling model of bearing was established by CFD software, and the test results were further analyzed. The results show that in the liquid nitrogen environment, the temperature rise of the bearing is not apparent, and with the increase of the chamber temperature, the lubrication state of the bearing changes, resulting in the temperature rise of the outer ring of the bearing becoming more and more severe. As the temperature of the test chamber increases, the friction force of the bearing increases first and then decreases under the action of multi-factor coupling of the surface topography of the bearing contact area after the test, it can be seen that at low temperature, the grinding debris of the bearing cage forms a film on the surface of the bearing raceway, which plays a particular lubricating role for the bearing. The research results provide test data and a theoretical basis for applying full ceramic ball bearings in aerospace and other fields and have important significance for improving the service life of high level equipment under extreme working conditions.

Research on the lubrication characteristics of PEEK retainer debris on the wear behavior of full ceramic bearings

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Keywords: Full-ceramic bearing; Drag force;Oil supply rate; Bearing vibration

The changes in geometric structure and lubrication state of full ceramic silicon nitride ball bearings under high-speed and light load conditions have led to increased bearing wear and premature loss of accuracy. Firstly, conduct friction and wear tests on the ball disc under oil lubrication, and obtain the wear coefficient of the material using different PEEK retainer debris as the lubricating material under oil lubrication. Secondly, the lubrication mechanism of the retainer debris was elucidated through surface morphology analysis using equipment such as SEM and XRD. Finally, based on the pseudo statics of rolling bearings and Archard wear theory, a wear life model of all ceramic bearings under solid oil lubrication was established. The influence of operating and structural parameters on bearing wear performance was explored through numerical solution, and the wear life of bearings was evaluated. The combined results indicate that the established model can predict the wear life of bearings well, and the error between the calculated and experimental results is within 7%.

Research on the Performance and Surface Quality of Micron Diamond Coated Tools in Cutting Workpieces of Different Materials

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Keywords: cutting performance, micron diamond coated tool, surface quality, tool wear, workpiece with different materials

Diamond coated tools have attracted much attention due to their high hardness, excellent wear resistance, and good impact toughness, and have gradually been applied to cutting lightweight and high-strength materials that are difficult to process, such as high-silicon aluminum alloy (CE11), carbon fiber reinforced resin matrix composites (CFRD), stone, and graphite. This study investigates the cutting performance of micron diamond coated tools when cutting workpieces of different materials and its impact on the surface quality of the workpieces. Through comparative experiments, the wear of the tool, cutting force, surface roughness, and surface integrity of the workpiece were analyzed. The experimental results show that the micron diamond coated tools exhibit excellent wear resistance and low cutting forces during the cutting of CE11 and CFRD, effectively improving the surface quality of the workpieces. However, when cutting stone and graphite, the tool wear is faster, the cutting forces are higher, and the surface quality is somewhat affected. This study provides valuable references and basis for the application of micron diamond coated tools in cutting workpieces of different materials.

Research on tribological behavior of self-lubricating cage of full ceramic ball bearing under cryogenic and oil-free lubrication conditions

by Zhongxian Xia | Yuhou Wu | He Wang | Junxing Tian | Longfei Gao | Jian Sun | Songhua Li | Hong Sun | Shenyang Jianzhu University | Shenyang Jianzhu University | Shenyang Jianzhu University | Shenyang Jianzhu University | Shenyang Jianzhu University | Shenyang Jianzhu University | Shenyang Jianzhu University | Shenyang Jianzhu University

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Keywords: cryogenic and oil-free lubrication conditions, full ceramic ball bearing, self-lubricating cage, tribological behavior

To explore the cage materials suitable for full ceramic ball bearing under cryogenic and oil-free lubrication conditions, the tribological behavior of Si3N4 ceramic balls and different matching materials under cryogenic and oil-free lubrication conditions is studied. The friction and wear mechanism between cage and ceramic balls and the transfer film forming mechanism are investigated based on the friction coefficient, wear rate and surface microstructure of the matching pairs. The results show that the friction coefficient of Si3N4 ceramic balls with different matching materials increases first and then fluctuates within a certain range. Compared with pure PEEK and PTFE, the fiber exposed to the worn surface of the polymer matrix composite can bear load after the matrix is furred, which increases the wear resistance of the materials. The reinforcement material with better self-lubricating performance can be used as the cryogenic lubricating medium of friction pairs, reducing the friction coefficient, so they have better comprehensive performance. Due to the load borne by fiber and the lubrication characteristics of graphite particles, C/C shows better lubrication and wear resistance, and the surface is relatively smooth. For C/SiC, because the addition of SiC increases the material hardness, cracks are easy to occur at the interface during the friction process with Si3N4 ceramic ball, which is characterized by brittle fracture, unstable friction coefficient, and high wear rate. The research results provide certain theoretical reference for the selection of full ceramic ball bearing cage material under ctyogenic and oil-free lubrication conditions.

Research on wear performance of diamond coated tools cutting glass-ceramic materials

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Keywords: cemented carbide tool, diamond coating, glass-ceramic, surface quality, wear resistance

In order to improve the service life and machining quality of cemented carbide tools, three types of diamond coatings were prepared on the surface of the tools in this study: micron diamond coating (MCD), micro-nano diamond coating (MNCD), and nano diamond coating (NCD). Through comparative experiments of cutting glass-ceramics, the influence of coating types and cutting parameters on the surface quality of workpieces, as well as the wear resistance of diamond-coated tools, were thoroughly investigated. The results showed that diamond-coated tools significantly outperform uncoated tools when cutting glass-ceramics. In particular, nano diamond-coated tools can achieve higher surface quality and lower roughness while ensuring cutting efficiency. In addition, diamond coated cutters can significantly improve the wear resistance of the cutter surface, effectively reducing the wear of the cutter during the machining process, thus prolonging the service life of the cutter and improving the machining accuracy and efficiency of the workpiece. Under the same machining parameters, the durability of coated cutters is ranked as follows: MCD > MNCD > NCD. This research result provides theoretical basis and practical guidance for the efficient machining of ceramic materials and the further optimization of diamond coated cutters.

Research Progress on Key Technology Theory and Methods of Ultra-precision Full Ceramic Bearing

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Symposium: 14. Part Surface Technology and Green Manufacturing (PST)
Keywords: HIPSN full ceramic ball bearing; Ultra-precision machining; High performance manufacturing; Extreme operating condition; Research progress

With the rapid progress of science and technology, the use conditions of high-end equipment bearings are increasingly harsh, such as ultra-high-speed conditions, wide temperature range of conditions, insulation conditions, etc. Ceramic materials with its high / low temperature resistance, wear resistance, corrosion resistance, anti-magnetic insulation, oil-free self-lubricating properties, is superior to the traditional metallic materials, hot isostatic pressing silicon nitride (HIPSN) is considered the most suitable for the manufacture of high-performance rolling bearings as a ceramic material. At this stage, the capability to design and manufacture all-ceramic bearings for extreme working conditions does not enable reliable replacement of traditional metallic bearings. Therefore, to carry out the research on the theory and method of high-performance manufacturing of ultra-precision all-ceramic bearings, and to form the basic theoretical system of high-performance ceramic bearing design and manufacturing has become a necessary path to enhance the level of high-end bearing research and development, and to promote the high-quality development of high-end equipment manufacturing industry.

This paper firstly elaborates on the technological demand for high-performance bearings applied in high-end equipment, and clarifies the necessity of developing high-performance all-ceramic bearings related key technologies and applications. It summarizes the development process of ceramic bearings and the current status of key technology development, focusing on the damage mechanism and failure behavior of ultra-precision HIPSN full ceramic ball bearing, the precision and performance control strategies of key components during precision machining, and the formation and evolution of in-service performance and other key scientific issues, key technologies and research results to discuss. Taking the design-manufacturing-service of ultra-precision ceramic bearings as the main line, the key technologies and research methods, such as forward design theory and method, high-performance manufacturing process, and the formation and evolution of service performance under extreme working conditions of ultra-precision all-ceramic bearings, are discussed in the outlook.

Research the lubrication on the dynamic characteristics of bearing rotor system

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Symposium: 14. Part Surface Technology and Green Manufacturing (PST)
Keywords: bearing, fluid-structure coupling, lubrication, temperature, vibration

In order to improve the service performance of ceramic ball bearings, the effective lubrication of ceramic ball bearings is realized. The fluid-structure coupling simulation model is established through Fluent software. The oil volume distribution, temperature field distribution and vibration in the bearing are analyzed under different lubricating oil viscosity and rotation speed. The accuracy of the model is verified by experiments under different working conditions. The results show that the amount of oil supplied for lubrication has a direct effect on the temperature of the bearing. Meanwhile, the bearing speed is sensitive to the vibration of the bearing. This theory has theoretical guiding significance for bearing design.

Stability Study of Beam Structures in the Integrated Construction of Prefabricated Buildings with an Attached Lifting Scaffold

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Keywords: Attached lifting scaffold; Prefabricated buildings; Beam structure; Hoop reinforcement optimization; Stability

Abstract. To investigate the stability of beam structures in prefabricated buildings with an attached lifting scaffold, the ABAQUS finite element analysis is employed. In this study, different model of beam attachment schemes are established, and the changes in force and deformation of each scheme in actual engineering are simulated, thereby analyzing the stability of each beam attachment scheme. To analyze the overall stress and deformation of the beam structures, different working conditions are set up to simulate the attachment scheme, and the key parts of the beam structures are optimized by densifying the hoop reinforcement. The results indicate that when the entire scaffold structure is attached to the beam structure, the stability of the beam structure with the scaffold is compromised. It is recommended to use attachment strategies such as spanning beams or attaching one end to the beam and one end to the wall. When the scaffold is in an ascending or descending condition, the beam structure supporting the lifting support will bear the entire weight of the scaffold, resulting in significant deformation. It is crucial to pay special attention to the deformation and cracking of the beam structure at the lifting support attachment point. Strengthening the hoop reinforcement of the beam structure can reduce the stress and deformation of key parts of the beam structure, and improve the safety and stability of the structure.

Study on Distribution of Lubricating Oil Film in Contact Micro-zone of Full Ceramic Ball Bearings and the Influence Mechanism on Service Performance

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Keywords: Full ceramic ball bearing, Lubricant oil film, Service performance, Simulation model

Compared with metal ball bearings, full ceramic ball bearings have more outstanding service performance under extreme working conditions. In order to reveal the lubrication mechanism of full ceramic ball bearing and improve the operation performance and service life of full ceramic ball bearing. In this paper, the friction, vibration and temperature rise characteristics of 6208 silicon nitride full ceramic deep groove ball bearing under the condition of oil lubrication are studied experimentally. Based on the test results and through theoretical calculation and simulation analysis, the distribution of lubricating oil film in bearing contact micro-zone under different working conditions was simulated. After that, the surface of contact micro-zone of full ceramic ball bearing is analyzed. It is found that there is an optimal oil supply for full ceramic ball bearing oil lubrication in service. Under the optimal oil supply lubrication, full film lubrication can be achieved, and the bearing exhibits the best characteristics of friction, vibration and temperature rise. Compared with the load, the rotational speed of the bearing has a decisive influence on the optimal oil supply. When the rotational speed and load are constant, the minimum oil film thickness and oil film pressure in the contact area of the rolling body decrease with the increase of angle ψ from the minimum stress point of the rolling body. Under the action of high contact stress, thin oil film will be formed in the bearing outer ring raceway. The research results of this paper have important guiding significance for revealing the oil lubrication mechanism of full ceramic ball bearing and enriching its lubrication theory and methods.

Study on Dynamic Characteristics of All-ceramic Ball Bearings at Low Temperature Environment

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Keywords: all-ceramic ball bearing;Dynamics;Low temperature working condition;Axial load;Vibration characteristics

All-ceramic ball bearing is a kind of special bearing with inner and outer ring and rolling body made of engineering ceramics. It has been widely used in aerospace, rail transportation, high-end manufacturing and other fields.For the study of the ceramic ball bearing dynamic performance at the extreme low temperature condition, the design of the low temperature environment simulation test device, in a silicon nitride ceramic ball bearings as the research object, the low temperature environment is studied by using bearing vibration test machine, vibration test and analysis of the temperature change on the ceramic ball bearing dynamic characteristics, the influence of the extreme ceramic ball bearings with dynamic response under different temperature conditions.The results show that under the action of single axial force, the vibration velocity of all-ceramic ball bearing increases gradually with the temperature decreasing from 20℃. When the temperature drops to minus 70℃, the vibration value reaches the maximum. When the temperature continues to decrease, the vibration value gradually decreases, and the vibration value changes gently when the temperature drops to minus 130℃.At a certain low temperature, with the increase of axial force, the vibration value first decreases, then increases slowly, and finally becomes flat.All-ceramic bearings can run smoothly when temperature and axial force remain constant or fluctuate within a small range.Research shows that all-ceramic ball bearings can meet the requirements of extreme temperature environment.

Study on friction and wear properties of silicon nitride-based element-doped diamond-like carbon films

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Keywords: diamond-like carbon films, elemental doping, failure mechanisms, silicon nitride ceramics, tribological properties

Silicon nitride ceramic materials have the characteristics of low density, high hardness, high temperature resistance, wear resistance and corrosion resistance, which are widely used in mechanical components such as bearings, cutting tools, blades, sealing rings and molds. However, silicon nitride ceramic materials have a high coefficient of friction (above 0.6) without lubrication, which is easy to cause energy loss and reduce their own lifetime. Diamond-like carbon（DLC）film with excellent properties such as high hardness, high wear resistance and low friction coefficient, whose thermal expansion coefficient is similar to silicon nitride ceramic material, can be used as a solid lubricating material to coat the surface of silicon nitride ceramic material in order to improve its friction and wear performance. In this paper, DLC films doped with Ti and Si elements and different thicknesses were coated on the surface of silicon nitride ceramic materials through a high-power pulsed magnetron sputtering method, to reduce residual stress and improve tribological properties. The surface morphology, cross-sectional structure, microstructure and mechanical properties of DLC films were characterized by scanning electron microscopy, X-ray photoelectron spectroscopy, Raman spectroscopy and nanoindentation test. The effects of different elements and doping ratios on the deposition rate, phase composition, structural characteristics and film-based binding force of DLC films were obtained. The friction coefficient and wear rate of different films were carried out by the friction and wear test under room temperature with silicon nitride balls as tribo-pairs. On this basis, the effects of the doping ratio of Ti and Si elements and thickness on the chemical composition, microstructure, mechanical and tribological properties of DLC films were discussed, further revealing the structural evolution law and failure mechanism of the friction surface of DLC film/silicon nitride ceramic material tribo-pairs.

Study on Nanoscale Scratching Characteristics of Single-crystal GaN

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Keywords: nano-indentation scratching; molecular dynamics; single-crystal GaN; subsurface damage; dislocation lines; plastic deformation

Single-crystal GaN is widely used in the manufacture of semiconductor devices such as integrated circuits and power devices by virtue of its small size, high hardness and high security. Nano-indentation scratching is the main technology for ultra-precision machining of single-crystal GaN surface, which can achieve the roughness of GaN at nanometer or sub-nanometer level. However, subsurface damage during nano-indentation scratching can reduce its service life. Therefore, the effects of normal loading force and scratch velocity on the subsurface damage layer of single-crystal GaN were investigated by establishing a simulation model of GaN nanocrystalline scratch using molecular dynamics method. The results show that the thickness of the subsurface damage layer is closely related to the ratio of the normal force to the tangential force during the scratching process: when the ratio of forces is large, the thickness of the damage layer is mainly determined by the number of dislocation lines in the transverse sliding of the crystal; when the ratio of forces is small, it is mainly determined by the number of dislocation lines in the cross slip of the crystal. Meanwhile, the scratching speed has no significant effect on the sub-surface damage layer of single-crystal GaN, but the high-speed scratching makes the sub-surface appear more plastic deformation characteristics, reducing the depth of the plastic deformation damage layer, which is conducive to the plastic removal of single-crystal GaN. Therefore, the sub-surface damage of single-crystal GaN can be controlled by changing the normal loading force and the scratching speed, laying a solid theoretical foundation for its application in semiconductor device manufacturing.

Study on the aging of diamond abrasives in the grinding process of silicon nitride ceramic balls

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Keywords: Silicon nitride□Ceramic balls□Diamond slurry□Efficient removal time

In order to obtain the maintenance time of high efficient removal of diamond abrasive in the lapping process of high precision silicon nitride ceramic ball, In this paper, the friction and wear characteristics of ceramic balls and cast iron with different concentrations of slurry under different working conditions were studied by using a friction and wear testing machine. The removal morphology of the ceramic sphere surface was observed by ultra-depth of field microscope and SEM . The removal form and transformation mechanism of silicon nitride by diamond abrasive under different working conditions were analyzed according to the surface characteristics. In this paper, a coupling model of grinding pressure, grinding speed, wear time and wear coefficient is established to predict the aging characteristics of diamond abrasives during the grinding process of silicon nitride ceramic balls. The results show that the friction coefficient of the silicon nitride friction pair and the wear rate of the silicon nitride ball decrease with the increase of load, and the friction coefficient of the silicon nitride friction pair and the wear of the silicon nitride ball increase first and then decrease with the increase of speed. As the grinding pressure and speed increases, the peak of wear per unit time becomes shorter. When the grinding pressure is 7.5N and the rotation speed is 150r/min, the maintenance time of efficient removal of diamond abrasive is about 1h. However, when the process parameters change, the maintenance time for efficient abrasive removal changes.

Study on the Influence of PTFE Lubrication Methods on the Friction and Wear Characteristics of Silicon Nitride Ceramics in a Wide Temperature Range Environment

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Keywords: PTFE transfer membrane; Silicon nitride ceramics;Lubrication method; Friction coefficient; Wide temperature range

In the wide temperature range environment, the bearing is easy to form instantaneous or short-term lack of oil, which leads to dry friction contact between bearing components and seriously affects the service performance of the bearing. The traditional oil or grease lubrication is no longer applicable, and the new solid self-lubricating will become the main lubrication method. In order to promote the development of self-lubricating silicon nitride (Si3N4) full ceramic bearing technology, the anti-wear and lubrication effects of PTFE materials with different lubrication methods on Si3N4 ceramics were investigated. The friction and wear tests of different lubrication methods in a wide temperature range (25°C~250°C) were carried out by a ball/disc friction and wear tester, including the friction and wear test of Si3N4 under PTFE powder lubrication and the friction and wear test of Si3N4/PTFE under dry friction. The results show that in the process of sliding friction, PTFE with different lubrication methods can form different forms of transfer films on the surface of Si3N4 ceramics, which can lubricate and protect Si3N4 ceramics. Among them, the transfer film with uniform thickness and complete surface has the best lubrication effect; In the temperature range of 25°C~250°C, the relationship between the overall friction coefficient of each lubrication mode is Si3N4/PTFE pair (0.141-0.228) > PTFE powder lubrication (0.070-0.121); Compared with Si3N4 ceramics directly contacting with PTFE solids, PTFE powder lubrication is more conducive to the formation of a transfer film with uniform thickness and wide coverage on the surface of silicon nitride ceramics; The research results provide a theoretical basis for the reasonable selection of lubrication methods for Si3N4 ceramic bearings under dry friction conditions, and further promote the development of high-performance Si3N4 ceramic bearing technology suitable for wide temperature range environment.

Study on Tribological Properties of Polydopamine as Lubricating Coating

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Keywords: Polydopamine;coating;friction and wear.

Abstract: The friction pair needs to be self-lubricated, as lubricating oil cannot be used in a vacuum and under extreme conditions. It is the main direction of development, through the preparation of coatings on the surface of the friction pair to achieve self-lubrication. In this paper, polydopamine (PDA) coating is prepared with silicon nitride as substrate, and its tribological properties are studied. First, the polydopamine solution is prepared with dopamine hydrochloride and Tris-HCI (TRIS). The PDA coating is prepared on silicon nitride substrate by sintering method, and the optimum sintering temperature is determined. Then, a friction-wear experiment was carried out to analyze the effects of frequency and load on the anti-wear and anti-friction properties of the PDA coating. The tribological properties of the polydopamine coating are investigated, and the wear mechanism and wear marks are analyzed. The results show that the PDA coating can reduce the friction coefficient and improve the tribological performance,compared with bare substrate.

Wear resistance of CrAlAgN coating on silicon nitride surface: Experimental study and first-principles calculations

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Keywords: First-Principles, Keywords□Silicon nitride, Thin film, Wear resistance

Abstract

To enhance the service life of silicon nitride bearings under oil-free lubrication, this study prepared CrAlN and CrAlAgN coatings on the surface of silicon nitride and investigated the wear resistance of the coatings under oil-free lubrication conditions. After doping with Ag elements, the wear resistance of the modified coatings was significantly improved. The CrAlAgN coatings showed significantly lower wear and friction coefficient compared to the CrAlN coatings. In addition, the strengthening mechanism of Ag atoms on ∑5(012) grain boundaries of CrAlN coatings was investigated using first-principles calculations. The results of the simulations reveal that after Ag atoms are doped at the grain boundaries of the coatings, the migration energy barrier of the vacancies between the grain boundaries is significantly increased, leading to an enhanced inhibition of dislocation emission by silver doping. The doping of Ag atoms improves the tensile strength of the coating grain boundaries, leading to an increase in the bonding strength of the grain boundaries.