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CONTENTS

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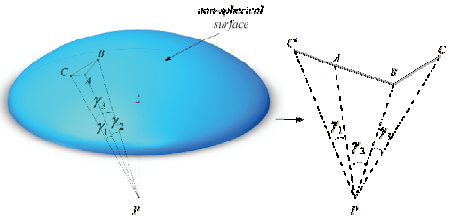
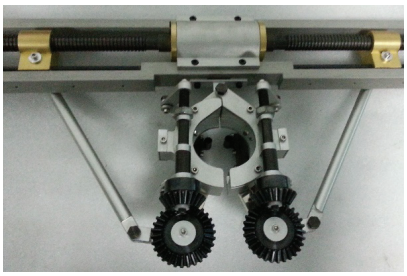
Special Issue on Reconfigurable Robots

Abstract: Space-deployable mechanisms can be used as supporting structures for large-diameter antennas in space engineering. This study proposes a novel method for constructing the surface design of space reflector antennas based on polar scissor units. The concurrency and deployability equations of the space scissor unit with definite surface constraints are derived using the rod and vector methods. Constraint equations of the spatial transformation for space n-edge polar scissor units are summarized. A new closed-loop deployable structure, called the polar scissor deployable antenna (PSDA), is designed by combining planar polar scissor units with spatial polar scissor units. The over-constrained problem is solved by releasing the curve constraint that locates at the end-point of the planar scissor mechanism. Kinematics simulation and error analysis are performed. The results show that the PSDA can effectively fit the paraboloid of revolution. Finally, deployment experiments verify the validity and feasibility of the proposed design method, which provides a new idea for the construction of large space-reflector antennas.



Abstract: As a type of multiconfiguration mechanism that can operate in an under-actuated state, metamorphic mechanisms were proposed more than two decades ago and attracted significant interest. Studies on structural synthesis of metamorphic mechanisms tend to focus more on metamorphic techniques and the structural synthesis of source mechanisms for metamorphic mechanisms. By designing different constraint architectures of metamorphic joints, multistructures can be obtained from the same source metamorphic mechanism. To determine the constraint architectures of metamorphic joints and their different assembly combinations, a kinematic status matrix and a corresponding constraint status matrix are constructed based on the metamorphic cyclogram of a source mechanism. According to the equivalent resistance gradient model and the constraint status matrix, an equivalent resistance matrix for the metamorphic joints is proposed. A structural synthesis matrix of the metamorphic mechanism is then obtained from the equivalent resistance matrix by deducing the constraint form vectors of the metamorphic joints. Furthermore, a kinematic diagram synthesis of the source metamorphic mechanism of aplanar single-loop metamorphic mechanism is proposed, which is based on only the 14 one- or zero-degrees-of-freedom linkage groups. The entire structural design method of a metamorphic mechanism is based on the structural synthesis matrix and is presented as a systematic process. Finally, the proposed structural design approach is illustrated by two examples to verify its feasibility and practicality. This study provides an effective method for designing a practical multi-mobility and multiconfiguration planar single-loop metamorphic mechanism with a single actuator.



CONTENTS

Vol. 33, October, 2020

(2020)33:70

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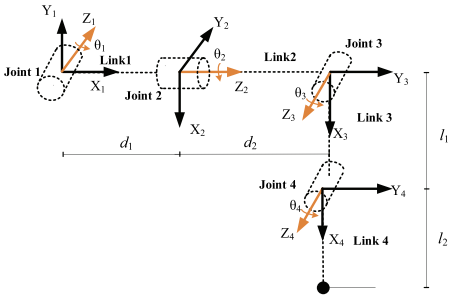
Design of Self-Reconfigurable Multiarm Robot Mechanism Based on Deployable Kinematic Chains

Fu-Qun Zhao • Sheng Guo • Haijun Su • Hai-Bo Qu • Ya-Qiong Chen

Abstract: As the structures of multiarm robots are serially arranged, the packaging and transportation of these robots are often inconvenient. The ability of these robots to operate objects must also be improved. Addressing this issue, this paper presents a type of multiarm robot that can be adequately folded into a designed area. The robot can achieve different operation modes by combining different arms and objects. First, deployable kinematic chains (DKCs) are designed, which can be folded into a designated area and be used as an arm structure in the multiarm robot mechanism. The strategy of a platform for storing DKCs is proposed. Based on the restrictions in the storage area and the characteristics of parallel mechanisms, a class of DKCs, called base assembly library, is obtained. Subsequently, an assembly method for the synthesis of the multiarm robot mechanism is proposed, which can be formed by the connection of a multiarm robot mechanism with an operation object based on a parallel mechanism structure. The formed parallel mechanism can achieve a reconfigurable characteristic when different DKCs connect to the operation object. Using this method, two types of multiarm robot mechanisms with four DKCs that can switch operation modes to perform different tasks through autonomous combination and release operation is proposed. The obtained mechanisms have observable advantages when compared with the traditional mechanisms, including optimizing the occupied volume during transportation and using parallel mechanism theory to analyze the switching of operation modes.



(2020)33:81

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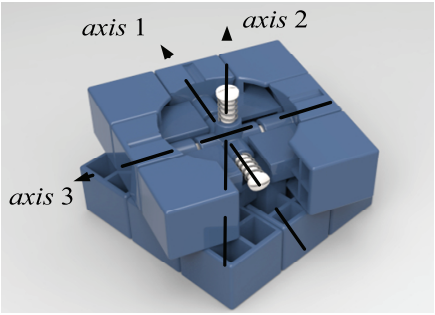
Constraint and Mobility Change Analysis of Rubik's Cube-inspired Reconfigurable Joints and Corresponding Parallel Mechanisms

Duanling Li • Pu Jia • Jiazhou Li • Dan Zhang • Xianwen Kong

Abstract: The current research of reconfigurable parallel mechanism mainly focuses on the construction of reconfigurable joints. Compared with the method of changing the mobility by physical locking joints, the geometric constraint has good controllability, and the constructed parallel mechanism has more configurations and wider application range. This paper presents a reconfigurable axis (rA) joint inspired and evolved from Rubik's Cubes, which have a unique feature of geometric and physical constraint of axes of joint. The effectiveness of the rA joint in the construction of the limb is analyzed, resulting in a change in mobility and topology of the parallel mechanism. The rA joint makes the angle among the three axes inside the groove changed arbitrarily. This change in mobility is completed by the case illustrated by a 3(rA)P(rA) reconfigurable parallel mechanism having variable mobility from 1 to 6 and having various special configurations including pure translations, pure rotations. The underlying principle of the metamorphosis of this rA joint is shown by investigating the dependence of the corresponding screw system comprising of line vectors, leading to evolution of the rA joint from two types of spherical joints to three types of variable Hooke joints and one revolute joint. The reconfigurable parallel mechanism alters its topology by rotating or locking the axis of rA joint to turn all limbs into different phases. The prototype of reconfigurable parallel mechanism is manufactured and all configurations are enumerated to verify the validity of the theoretical method by physical experiments.



CONTENTS

Vol. 33, October, 2020

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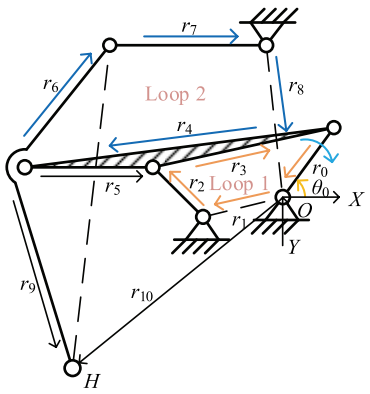
Development and Analysis of a Closed-Chain Wheel-Leg Mobile Platform

Chaoran Wei • Yanan Yao • Jianxu Wu • Ran Liu



Abstract: Current research concerning legged platforms and wheeled platforms primarily focuses on terrain adaptive capability and speed capability, respectively. Compared with wheeled platforms, legged platforms with a closed-chain mechanism still present deficiencies regarding speed ability. To integrate the advantages of these two types of platforms, a wheel-leg mobile platform with two modes based on a closed-chain mechanism is proposed. First, a closed-chain mechanism that generates a high-knee trajectory in legged mode is designed and analyzed based on kinematic analysis. To improve the platform's obstacle-surmounting performance, the dimensional parameters of the closed-chain mechanism are optimized and the design requirements for the platform's frame are analyzed. In addition, the particular structure of the leg group is designed to realize transformation between legged mode and wheeled mode. The mobility of the constructed platform is calculated through an obstacle-surmounting probability analysis. The performances of the two motion modes are analyzed and compared by conducting dynamic simulations. Finally, experiments are carried out to verify both the theoretical analyses and the prototype performance. This study proposes a new approach to designing wheel-leg platforms with prominent speed ability and mobility based on a closed-chain mechanism.

(2020)33:75

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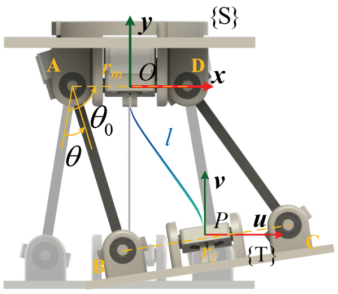
A Stiffness Variable Passive Compliance Device with Reconfigurable Elastic Inner Skeleton and Origami Shell

Zhuang Zhang • Genliang Chen • Weicheng Fan • Wei Yan • Lingyu Kong • Hao Wang



Abstract: Devices with variable stiffness are drawing more and more attention with the growing interests of human-robot interaction, wearable robotics, rehabilitation robotics, etc. In this paper, the authors report on the design, analysis and experiments of a stiffness variable passive compliant device whose structure is a combination of a reconfigurable elastic inner skeleton and an origami shell. The main concept of the reconfigurable skeleton is to have two elastic trapezoid four-bar linkages arranged in orthogonal. The stiffness variation generates from the passive deflection of the elastic limbs and is realized by actively switching the arrangement of the leaf springs and the passive joints in a fast, simple and straightforward manner. The kinetostatics and the compliance of the device are analyzed based on an efficient approach to the large deflection problem of the elastic links. A prototype is fabricated to conduct experiments for the assessment of the proposed concept. The results show that the prototype possesses relatively low stiffness under the compliant status and high stiffness under the stiff status with a status switching speed around 80 ms.

CONTENTS

Vol. 33, October, 2020

CONTENTS

Vol. 33, October, 2020

Review

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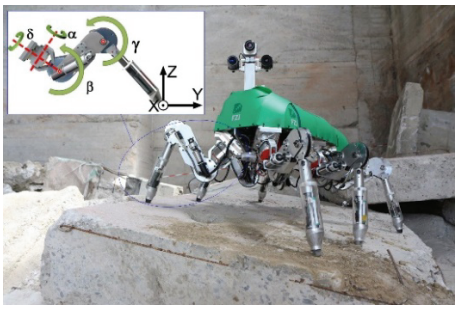
Mechanism, Actuation, Perception, and Control of Highly Dynamic Multilegged Robots: A Review

Jun He • Feng Gao



Abstract: Multilegged robots have the potential to serve as assistants for humans, replacing them in performing dangerous, dull, or unclean tasks. However, they are still far from being sufficiently versatile and robust for many applications. This paper addresses key points that might yield breakthroughs for highly dynamic multilegged robots with the abilities of running (or jumping and hopping) and self-balancing. First, 21 typical multilegged robots from the last five years are surveyed, and the most impressive performances of these robots are presented. Second, current developments regarding key technologies of highly dynamic multilegged robots are reviewed in detail. The latest leg mechanisms with serial-parallel hybrid topologies and rigid–flexible coupling configurations are analyzed. Then, the development trends of three typical actuators, namely hydraulic, quasi-direct drive, and serial elastic actuators, are discussed. After that, the sensors and modeling methods used for perception are surveyed. Furthermore, this paper pays special attention to the review of control approaches since control is a great challenge for highly dynamic multilegged robots. Four dynamics-based control methods and two model-free control methods are described in detail. Third, key open topics of future research concerning the mechanism, actuation, perception, and control of highly dynamic multilegged robots are proposed. This paper reviews the state of the art development for multilegged robots, and discusses the future trend of multilegged robots.

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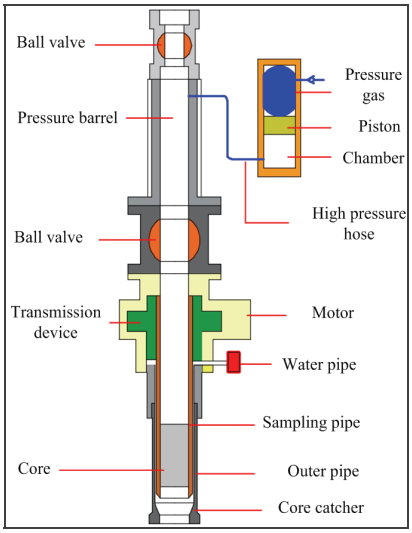
Review and Analysis of Key Techniques in Marine Sediment Sampling

Shudong He • YouduoPeng • Yongping Jin • Buyan Wan • Guangping Liu



Abstract: Deep-sea sediment is extremely important inmarine scientific research, such as that concerning marine geology and microbial communities. The research findings are closely related to the in-situ information of the sediment. One prerequisite for investigations of deep-sea sediment is providing sampling techniques capable of preventing distortion during recovery. As the fruit of such sampling techniques, samplers designed for obtaining sediment have become indispensable equipment, owing to their low cost, light weight, compactness, easy operation, and high adaptability to sea conditions. This paper introduces the research and application of typical deep-sea sediment samplers. Then, a representative sampler recently developed in China is analyzed. On this basis, a review and analysis is conducted regarding the key techniques of various deep-sea sediment samplers, including sealing, pressure and temperature retaining, low-disturbance sampling, and no-pressure drop transfer. Then, the shortcomings in the key techniques for deep-sea sediment sampling are identified. Finally, prospects for the future development of key techniques for deep-sea sediment sampling are proposed, from the perspectives of structural diversification, functional integration, intelligent operation, and high-fidelity samples. This paper summarizes the existing samplers in the context of the key techniques mentioned above, and can provide reference for the optimized design of samplers and development of key sampling techniques.

CONTENTS

Vol. 33, October, 2020

Intelligent Manufacturing Technology

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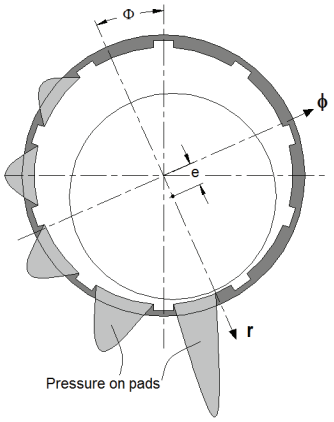
A New Method to Calculate Water Film Stiffness and Damping for Water Lubricated Bearing with Multiple Axial Grooves

Guojun Ren

Abstract: Water lubricated guide bearings for hydro turbines and pumps are conventionally designed with multiple axial grooves to provide effectively cooling and flushing away abrasives. Due to the variety of groove configuration in terms of number and size, a predication of their performance is difficult. This paper deals with an analytical procedure to investigate groove effect on load capacity, stiffness and damping for this type of bearing where it is considered as an assembly of many inclined slide bearings. The result can be applied to bearings made of hard materials combined with low bearing pressure.



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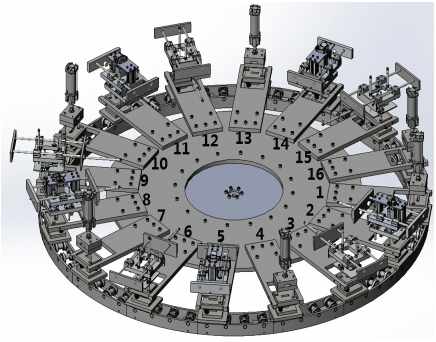
Blade Segment with a 3D Lattice of Diamond Grits Fabricated via an Additive Manufacturing Process

Bin Chen • Peng Chen • Yongjun Huang • Xiangxi Xu • Yibo Liu • Shuangxi Wang

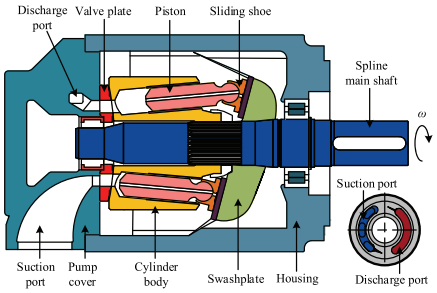
Abstract: Diamond tools with orderly arrangements of diamond grits have drawn considerable attention in the machining field owing to their outstanding advantages of high sharpness and long service life. This diamond super tool, as well as the manufacturing equipment, has been unavailable to Chinese enterprises for a long time due to patents. In this paper, a diamond blade segment with a 3D lattice of diamond grits was additively manufactured using a new type of cold pressing equipment (AME100). The equipment, designed with a rotary working platform and 16 molding stations, can be used to additively manufacture segments with diamond grits arranged in an orderly fashion, layer by layer; under this additive manufacturing process, at least 216000 pcs of diamond green segments with five orderly arranged grit layers can be produced per month. The microstructure of the segment was observed via SEM and the diamond blade fabricated using these segments was compared to other commercial cutting tools. The experimental results showed that the 3D lattice of diamond grits was formed in the green segment. The filling rate of diamond grits in the lattice could be guaranteed to be above 95%; this is much higher than the 90% filling rate of the automatic array system (ARIX). When used to cut stone, the cutting amount of the blade with segments made by AME100 is two times that of ordinary tools, with the same diamond concentration. When used to dry cut reinforced concrete, its cutting speed is 10% faster than that of ARIX. Under wet cutting conditions, its service life is twice that of ARIX. By applying the machine vision online inspection system and a special needle jig with a negative pressure system, this study developed a piece of additive manufacturing equipment for efficiently fabricating blade segments with a 3D lattice of diamond grits.



(2020)33:67
DOI: 10.1186/s10033-020-00486-8

Cavitation of a Submerged Jet at the Spherical Valve Plate / Cylinder Block Interface for Axial Piston Pump

Bin Zhao • Weiwei Guo • Long Quan



Abstract: The spherical valve plate/cylinder block pair has the advantages of strong overturning resistance and large bearing area. However, the configurations of the unloading and pre-boosting triangular grooves on the spherical valve plate are different from those in the planar valve plate, resulting in special cavitation phenomenon on the spherical port plate pair. In order to study cavitation characteristics of spherical port plate pair, a dynamic CFD model of the piston pump including turbulence model, cavitation model and fluid compressibility is established. A detailed UDF compilation scheme is provided for modelling of the micron-sized spherical oil film mesh, which makes up for the lack of research on the meshing of the spherical oil film. In this paper, using CFD simulation tools, from the perspectives of pressure field, velocity field and gas volume fraction change, a detailed analysis of the transient evolution of the submerged cavitation jet in a axial piston pump with spherical valve plate is carried out. The study indicates the movement direction of the cavitation cloud cluster through the cloud image and the velocity vector direction of the observation point. The sharp decrease of velocity and gas volume fraction indicates the collapse phenomenon of bubbles on the part wall surface. These discoveries verify the special erosion effect in case of the spherical valve plate/cylinder block pair. The submerged cavitation jet generated by the unloading triangular grooves distributed on the spherical valve plate not only cause denudation of the inner wall surface of the valve plate, but also cause strong impact and denudation on the lower surface of the cylinder body. Finally, the direction of the unloading triangular groove was modified to extend the distance between it and the wall surface which can effectively alleviate the erosion effect.

Smart Materials

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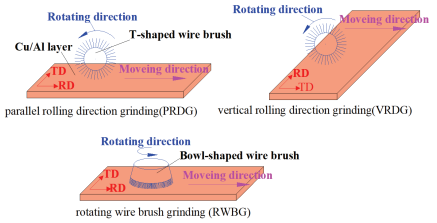
Effect of Mechanical Surface Treatment on the Bonding Mechanism and Properties of Cold-Rolled Cu/Al Clad Plate

Jianchao Han • Hui Niu • Sha Li • Zhongkai Ren • Yi Jia • Tao Wang • A I Plokhikh • Qingxue Huang



Abstract: In the case of valuable cold-rolled Cu/Al clad plates, billet surface treatment before rolling is a significant process that can affect the bonding efficiency and quality. While the current studies primarily focus on the influence of rolling parameters, insufficient attention has been paid to surface treatment. In this study, the effects of mechanical surface treatment on the bonding mechanism and bonding properties of cold-rolled Cu/Al clad plates were investigated. The results showed that different mechanical surface treatments have significant effects on the surface morphology, roughness, and residual stress. In addition, the effect of surface mechanical treatment on bonding quality was also observed to be critical. When the grinding direction was consistent with the rolling direction (RD), the bonding quality of the Cu/Al clad plates was significantly improved. After surface treatment along the RD for 20 s, the Cu/Al clad plates showed the highest shear strength (78 MPa), approximately four times as high as that of the unpolished samples. Simultaneously, the peel strength of this process was also significantly higher than that achieved via the other processes. Finally, on the basis of the surface morphology, roughness, and residual stress, the effect of surface treatment on the bonding mechanism and bonding properties of Cu/Al clad plates was analyzed. This study proposes a deeper understanding of the bonding behavior and bonding mechanism for cold rolled clad plates processed via mechanical surface treatment.

CONTENTS

Vol. 33, October, 2020

(2020)33:76

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Investigation on Yield Behavior of 7075-T6 Aluminum Alloy at Elevated Temperatures

Jianping Lin • Xingyu Bao • Yong Hou • Junying Min • Xinlei Qu • Zhimin Tao • Jiajie Chen

Abstract: Aluminum alloys have drawn considerable attention in the area of automotive lightweight. High strength aluminum alloys are usually deformed at elevated temperatures due to their poor formability at room temperature. In this work, the yield behavior of 7075 aluminum alloy in T6 temper (AA7075-T6)within the temperature ranging from 25 ℃ to 230 ℃ was investigated. Uniaxial and biaxial tensile tests with the aid of induction heating system were performed to determine the stress vs. strain curves and the yield loci of AA7075-T6 at elevated temperatures, respectively. Von Mises, Hill48 and Yld2000-2d yield criteria were applied to predicting yield loci which were compared with experimentally measured yield loci of the AA7075-T6. Results show that yield stress corresponding to the same equivalent plastic strain decreases with increasing temperature within the investigated temperature range and the shape of yield loci evolves nearly negligibly. The experimental yield locus expands with an increase of equivalent plastic strain at the same temperature and the work hardening rate of AA7075-T6 exhibits obvious stress-state-dependency. The non-quadratic Yld2000-2d yield criterion describes the yield surfaces of AA7075-T6 more accurately than the quadratic von Mises and Hill48 yield criteria, and an exponent of 14 in the Yld2000-2d yield function gives the optimal predictions for the AA7075-T6 at all investigated temperatures.