Contents

Forum on the Development of Bionic Engineering

A Research and Innovation Frontier for Bio-inspired Technologies

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Abstract

A young and rapidly growing interdisciplinary field of research in biosensing and bioactuation (BSBA) has been emerged to enable engineers to work with bio scientists and other specialists to discover new knowledge in living systems and their interface with engineering systems. These discoveries could lead to innovation in bio-inspired technologies. The common national-need application areas for use of such advanced technologies are very broad and include infrastructure protection and sustainability, detection of environmental pollution and security agents, and natural disaster foresasting and mitigation. The National Science Foundation (NSF) of USA made twelve BSBA interdisciplinary team research awards under a FY 09 EFRI initiative. These projects are expected to pioneer a long-term research frontier overlaying multiple traditional disciplinary domains that would lead to the next generation of engineering systems with autonomy and cognition, and result in transformative impacts to many critical needs of the society. A report on this program will be presented in this paper. Opportunities and planned actions for international research collaboration in this area with Europe, Japan, China, and Korea etc. have been actively pursued. An updated account of such collaborative programs will be also made.

Biomimetics – research and innovative development to turn scientific knowledge into beneficial practice

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Abstract

BIOKON international is a non-profit organization and focuses on international initiatives and measures to build an integrative network of leading experts in the field of biomimetics. The primary objective is to make biomimetics useful as a source of ideas and innovations for technology, business, and society. The association combines resources and competencies in the area of biomimetics, bionics and bio-inspired technologies to achieve sustained success. By sharing our knowledge biomimetics products and technologies as drivers of innovation are promoted.

The presentation focuses on innovation management and how biomimetics networks contribute to turn scientific knowledge into beneficial practice.

Biomimetics - interdisciplinarity and networking

Biomimetics is based on the interdisciplinary link that extends from fundamental research to multi-faceted high-tech applications in and with a previously unknown scope and reach. It relies on interaction between biological and technical expertise with a clearly application-orientated approach. Successful transfer of knowledge concerning the structures, processes and characteristics of living systems to technical systems and their application in industrial practice is a “conditio sine qua non” for intelligible communication, correspondence and cooperation between disciplines.

The complexity of today´s challenges means that a single discipline is unable to face them alone. An interdisciplinary dialogue is vital to coping with these challenges, and precisely this is one of biomimetics´ strongest points.

Networked structures as a criterion for success

Nature is one of the most successful innovators of all times! For some 3.8 billion years, nature has developed, tested and optimised new solutions to problems time and time again. Biomimetics plays a key role whenever humans seek to leverage solutions successfully tested in nature´s test lab for our knowledge society. This is why it is not just a melting pot of different biological, scientific and engineering disciplines, but a field of research in which fundamental research and technical applicability mesh at a very early stage.

Biomimetics combines biology and technology. It focuses on tried-and-trusted natural solutions and their systematic implementation in technology. Scientists and engineers from various fields collaborate in an interdisciplinary approach to generate and launch

innovative ideas and developments. And precisely this is a golden opportunity for businesses. After all biomimetics delivers innovations. Our ambitious goal is often that of developing new concepts and products that extend well beyond what appears to be technologically feasible today. This is why biomimetics is gaining in popularity and increasingly being adopted in industrial research and development.

Biomimetics ideas and concepts play a role in many development and optimisation processes and are increasingly finding their way into the final product - although the contribution made by biomimetics is not always explicitly mentioned. For example, when Opel achieves a new standard with respect to lightweight construction and structural rigidity with a biomimetically optimised stub axle, this doesn´t mean that the car will be promoted as a biomimetics product. This also applies to product contributions in other fields: aircraft wings, MP3, Velcro fasteners - all of which are established products for which nature provided the role models. There is one important thing to note here: it is not just a case of copying nature, but of discovering the underlying principles and methods, and converting them into tangible added value for technology, business and society - and this necessitates interdisciplinary networking and cooperation.

_BIO_KON - biomimetics network of excellence

The biomimetics network of excellence, *BIO*KON, was founded in 2001 with support from the German Federal Ministry of Education and Research (BMBF). In 2004, *BIO*KON adopted the legal status of a non-profit association. *BIO*KON is the umbrella for over 90 universities, research institutions, businesses and individuals from the whole of Germany and Europe, all of whom work in the field of biomimetics.

The major aims of *BIO*KON are: bundling and networking existing expert knowledge, implementing or accompanying R&D projects, training and educational efforts, and offering and coordinating PR for bionics. *BIO*KON converts knowledge into added value and acts as a lobbyist and provider of impetus. In recent years, *BIO*KON has established itself as a central hub for information on and contacts in bionics and thus developed into a peer-level liaison entity for various user groups or user industries. *BIO*KON has become a "drive belt for patented, natural solutions".

The biomimetics network of excellence is founded on a growing number of regional nodes which are distributed throughout Germany and research into various sub-disciplines in the field of biomimetics. The members of *BIO*KON in turn liaise with leading research institutions all over the world. Many industrial enterprises in Germany, and increasingly abroad, already draw on the competency pool offered by *BIO*KON, adopting biomimetics ideas, using expert consultancy, involving *BIO*KON experts in their R&D work, or commissioning tangible research projects. Some major companies have created their own liaison interfaces for cooperation with *BIOKON*; small to medium sized enterprises benefit from the research fed to them by universities and colleges and have been able to assert

themselves more easily on today´s markets thanks to the rapid implementation of tangible product ideas and biomimetics methods. Enquiries from companies in turn generate new bionic topics that lead to a stronger focus of fundamental biological research on application-relevant questions.

Besides *BIO*KON, there are local networks in Germany, such as the Biomimetics Competency Network based in Baden Wuerttemberg, the Bionic Innovation Centre (B-I-C) at Bremen university, or the bionic engineering network (BEN) in Saarland. All of them are integrated vertically with the national structures and pillars of these structures at a regional level.

*BIO*KON has collaborated with the German Engineering Association (Verein Deutscher Ingenieure (VDI)) and the German Federal Ministries of Education and Research (BMBF), Economics and Technology (BMWi) and the Environment (BMU), as well as the German government´s national liaison offices for the European framework research programme to develop the technology roadmap "Bionik 2020". In the field of biomimetics, Germany is in the lucky position of being one of the most prominent research locations worldwide. Maintaining the high scientific level of German research in a country with little in the line of raw materials will continue to be a major concern in future. To allow this to happen, it is imperative to further reinforce the international reputation and integrate biomimetics approaches permanently and rapidly with industrial innovation processes. In particular, this means intensifying knowledge transfer to industry. This explains why transfer of know-how is so firmly in the focus of the biomimetics roadmap.

Internationalisation: BIOKON international – The Biomimetics Association

The national networking structures created by *BIO*KON are a genuine success story. At the same time, wide reaching international contacts and working relationships, especially to European partners, have been established in recent years. The foundation of the international umbrella organisation BIOKON international - The Biomimetics Association in March 2009 was the next logical step towards international networking and institutionalisation. The registered office of this umbrella organisation for national bionics networks is Berlin; the offices are run by *BIO*KON.

Shortly after its foundation, BIOKON international already has more than 80 members (member institutes) from 11 different countries and acts as a recognised stakeholder on an international level. Its major activities focus on developing mutual R&D projects, generating and implementing financing options for biomimetics research and development at an international level, and ultimately on firmly establishing biomimetics as a driver of innovation for new products and technologies on a European and international platform.

Networks as a driver of innovation

Biomimetics networks bundle the expertise from various fields of biological, natural and engineering sciences - and increasingly from business - in a versatile manner and at many levels. Biomimetics solutions and optimisation strategies provide an increasingly targeted approach to novel products and technologies and have proved their superiority to competitive solutions. Another characteristic attributable to biomimetics developments is that they do not just lead to a single product line, but to a wide ranging product portfolio that often spans many branches of industry. Accompanying the prime example of biomimetics, the Lotus Effect®, a seminal innovation that is one of the 12 most significant innovations to have come from Germany in the last fifty years, there are now 200 auxiliary innovations. Other examples besides the Lotus Effect® include the use of the optimisation programs by Professor Mattheck and Professor Rechenberg, and more recently the Fin Ray Effect® by EvoLogics, of which the same can be said.

However, the path from a biomimetics idea to a marketable product is typically a long one. Decisive steps along this path include manufacturing of technical prototypes and functional models, close collaboration on mutual R&D projects between stakeholders in science and industry, and sponsorship of young scientists. This is precisely what networked structures and the competency networks discussed early support.

Biomimetics: Challenges, Development and Opportunities

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Abstract

Biomimetics deals with knowledge transfer of deep principles from animated nature to technology and the arts. Nature excels at combining materials, structures and processes. A classic example for successful biomimetics is the aerodynamic shape of airplanes inspired by birds. Current biomimetic developments range from nanostructured surfaces (self cleaning, antireflective) to whole buildings (Beijing National Stadium).

The scarcity of available resources is one of the major challenges for humankind. Energy, raw materials, food and water are increasingly short in supply. Compared to conventional engineering products, biomimetic applications usually offer an improved effort-performance relationship. This makes the biomimetic approach an ideal tool to tackle major global challenges as defined by the United Nations Millennium Project.

This lecture will deal with biomimetic engineering approaches in dealing with these major challenges, and outline opportunities that arise from this methodology. Based on detailed examples, solutions will be presented and the underlying principles explained. Another goal of this presentation will be to illustrate where biomimetics is currently heading and which issues can come up in connection with consequent application of biomimetics.

Plenaries

Biomimetic superhydrophobic surfaces and their application: Lotus- and Salvinia-Effect

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Abstract

Superhydrophobic technical surfaces are of high scientific and economic interest because of their remarkable properties. However, the most intriguing surfaces evolved in plants and animals. In the lotus flower (*Nelumbo nucifera*) a combination of micro- and nanostructures, together with a hydrophobic chemistry, generates a superhydrophobic leaf surface with self-cleaning properties. We successfully transferred the underlying physico-chemical principles to technical prototypes and since the late 1990s Lotus-Effect® products like façade paint were introduced. Whereas the superhydrophobic and self-cleaning abilities are well explored in biological as well as technical surfaces, little attention was given to their air-retaining properties under water. Only recently the immense potential of air-retaining surfaces e.g. for low friction fluid transport and drag reducing ship coatings has started to be explored. A mayor problem of Lotus mimicking superhydrophobic surfaces is the limited persistence of the retained air, especially under rough flow conditions. However, a variety of floating or diving plant and animal species exist (e.g. the water fern *Salvinia*), which possess surfaces optimised for long term air retention. First biomimetic prototypes are already capable of retaining air films for several weeks. In a large-scale experiment, a ship hull with a prototypic coating showed a drag reduction of up to 10%.

Literature and further information: www.nees.uni-bonn.de , www.lotus-effect.com

Biomimetics on gecko locomotion: Behaviour, reaction forces and Bio-inspired wall-climbing robots

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Abstract

Gecko's excellent locomotion abilities originated from many synergetic effects arising from its unique hierarchical foot structures have inspired the micro-fabrication of adhesive foot for gecko-mimicking robots. However, the moving ability of gecko-mimicking robots still lags far behind that of gecko largely because many important issues governing the gecko locomotion (for instance, how a gecko does enhance attaching reliability and modulate the reaction forces to optimize its locomotion performance) are still poorly understood. The discontinuous constrain associated with the foot-substrate attachment and transform from the swing to stance phase has made the locomotive dynamic prediction very difficult, so the measurements of the reaction forces become one of the most effective approaches to the discovery of the legged locomotion secrets. By developing a high-resolution three-dimensional (3D) force sensor array, we have, for the first time, measured the reaction forces on individual feet and toes of a freely-moving gecko on various substrates. The force measurements, coupled with motion analyses by an attached high speed video-camera, enabled us to reveal the details on how a gecko can govern its motion by modulating 3D reaction forces. We found that gecko's toe generates unidirectional shear force along the toe radial, leading to the formation of reverse shear forces between the first and last toes. The redundant shear forces greatly enhance the attachment reliability. When walking on the floor, gecko reduces the reaction force and enhances its locomotion abilities by lifting its body from the floor only. While crawling on a ceiling, gecko ensures a reliable attachment by limiting the support angle slightly smaller than the critical detaching angle. It reduces the reaction force by keeping the support angle maximum. Gecko holds on the ceiling by shear forces acting on each gecko feet along the direction pulling away from body. It reliably sticks on a wall and even secures a self-locking attachment by modulating the support angle of the reaction forces to be smaller than (about half of) the critical detaching angle. We also found that the pattern of reaction forces depends heavily on the slope of substrate. These newly-discovered mechanical and dynamic roles governing the gecko locomotion should have an important implication in developing advanced gecko-mimicking robots.

Biomimetics: Lessons from Nature

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Abstract

Nature has developed materials, objects, and processes which function from the macroscale to the nanoscale. These have gone through evolution over 3.8 billion years. The emerging field of biomimetics allows one to mimic biology or nature to develop nanomaterials, nanodevices, and processes[1 1,2]. Properties of biological materials and surfaces result from a complex interplay between surface morphology and physical and chemical properties. Hierarchical structures with dimensions of features ranging from macroscale to the nanoscale are extremely common in nature to provide properties of interest. Molecular scale devices, superhydrophobicity, self-cleaning, drag reduction in fluid flow, energy conversion and conservation, high adhesion, reversible adhesion, aerodynamic lift, materials and fibers with high mechanical strength, biological self-assembly, anti-reflection, structural coloration, thermal insulation, self-healing, and sensory aid mechanisms are some of the examples found in nature which are of commercial interest. This talk will provide a broad overview of four selected objects of interest found in nature and applications under development or available in the marketplace. These will include Lotus Effect used to develop superhydrophobic and self-cleaning surfaces with low adhesion[3-5], Rose Petal Effect used to develop superhydrophobic surfaces with high adhesion[6], Gecko adhesion to develop surfaces with reversible adhesion[7], and shark skin to develop surfaces with low fluid drag[8].

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Mimicking Bone Structure and Function with Structural Composite Materials

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Abstract

This paper reviews the progress that has been made in fabricating biomimetic bones structures using synthetic composite materials. The specification for long bone applications is developed and we identify the candidate materials for delivering cortical and cancellous bone properties and function. The role of composite materials is discussed together with the factors influencing fibre and matrix type. Challenges associated with moderating their performance in-vivo are discussed, relating to the properties of the starting materials and the dependence, for fibre reinforced systems, on interface quality. Fabrication routes for producing complex biomimetic structures are also reviewed and the state of current clinical developments is described along with the associated technical and regulatory issues.

Keywords: Bone, Composite, Ceramic, Polymer, Fibres, Surface Modification

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Keynotes

Analysis of multivariate coupling mechanism of Lepidoptera insect wings' surface superhydrophobicity

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Abstract

The surface shape, structure, biomaterial and wettability of Lepidoptera insect wings (Butterflies and moths) were qualitatively and quantitatively studied by means of a stereoscopic microscope, a scanning electronic microscope, fourier transform infrared spectroscopy(FT-IR) and the interface contact angle measurement. The observation shows that Lepidoptera insect wings'surface has stronger hydrophobicity. There are scales arranged like overlapping tiles on the surface of the wings. The shapes of the scales are different between species. The surface of the scale is structured by grooves and vertical gibbosities. The length of butterfly wing scale is 65~150μm，width 35~70μm，distance 48~91μm. The height of vertical gibbosity on wing scale is 200~900 nm，width 200~840 nm，distance 1.06~2.74μm. The length of moth wing scale is 121~454μm，width 44~182μm，distance 18~145μm. The height of vertical gibbosity on wing scale is 257~1971 nm，width 171~457 nm，distance 971~2946μm. The biomaterial components of the wing scale are mostly made up of protein, lipids and chitin. The observation also shows that the surfaces of the wings with scales are more hydrophobic. For example, the contact angle for wings with scales is in the range from 144.8° to 152.9°, while that those without scales is from 90.0° to 115.9°. According as Cassie model, the equation of wettability on Lepidoptera insect wing surface is established and the hydrophobic mechanism is analyzed. It is concluded that the hydrophobicity of Lepidoptera insect wings is induced by the multivariate coupling of the shape, structures and biomaterial of the scales.

Keywords: Lepidoptera insect wings, Moth, Butterfly, Scale, Hydrophobicity, Biomaterial, Shape, Structure, Coupling

Anti-erosion Function in Animals and its Biomimetic Application

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Abstract

Material failure is usually caused by corrosion, wear and mechanical damage. According to previous researches, erosion wear holds about 8% of regular wear in industrial production. In the present work, a new approach which adopted the idea of coupling bionics to improve erosion resistance of machine parts was presented, and the desert scorpion (*Leiurus quinquestriatus*) was taken as the research object. The anti-erosion characteristic rules and mechanism of desert scorpion's surface under the dynamics effect of gas/solid mixed media were researched, especially the comprehensive influence mechanism of surface morphology, microstructure, creature flexibility and many other factors were studied. Simulation by ANSYS/LS-DYNA finite element software was applied to predict the relative erosion severity, and experiment optimum design theory was employed to design experiment scheme. Silica sand of particle size 105~830 μm was used as the erodent. Samples with the coupled bionic configurations of groove and flexibility were produced. The erosion tests were carried out to validate the simulation results obtained. It is shown that the predicted results are in agreement with those obtained from the experiments. Regression equation between erosion rate and experiment factors of coupling of flexibility and surface morphology were obtained. And contrast tests were carried out at the best and worst test points of erosion resistance for three samples of groove, smooth and flexibility, smooth. Contrast tests showed that the erosion resistance trend occurred in such order with the best erosion resistance as coupling sample, the second was smooth and flexibility, the third was groove, the fourth was smooth, and the increasing rate of erosion resistance in sequence of 32.8%, 28.86%, 16.03% in the best test point. But in the poorest point, the erosion resistance trend occurred in such order with the best erosion resistance as coupling sample, the second was groove, the third was smooth and flexibility, the fourth was smooth, and the increasing rate of erosion resistance in sequence of 35.74%, 25.53%, 5.59%, respectively. The morphologies of eroded surface were examined by the Scanning Electron Microscope (SEM), and the possible wear mechanism was discussed.

Keywords: Erosion, Coupling bionics, ANSYS/LS-DYNA, Experiment optimum design

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Biomimetic Microsystems in Living Cell Studies

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Abstract

Microsystems refer to miniaturized devices which have functional features and dimensions in sub-millimeter scale. They do not only process information as integrated circuits but also interface with the surrounding environment to process matter by sensing and/or actuation functions. Microsystems integrate electric, mechanic, optic and fluidic features and components into functional entities using such technologies as micro- and biosensors, microactuators, microfluidics, microrobotics, and micro-optics.

The use of living human cell cultures provides an ethically, economically and scientifically advantageous alternative for laboratory animals in disease studies, toxicity testing and drug development, for example. Furthermore, stem cell and primary cell cultures provide a promising new method for therapy of various diseases. There are, however, huge gaps in understanding the exact disease, differentiation and drug effect mechanisms at a cell level. To fill these gaps, new technological innovations and tools are needed.

Our group develops new biomimetic microsystems for understanding the various cellular mechanisms. A more than 10-year experience shows that for a successful development of systems for living cells, multidisciplinary research teams are inevitable. Our micro- and nanosystems research group collaborates with material scientists, signal processing experts, cell biologists and clinicians to achieve the goals. In this presentation, an outlook on the organization and development of a multidisciplinary research environment is given.

To study cellular mechanisms in-vitro, the key is to provide for the cells an environment which mimics as closely as possible the "normal" conditions in-vivo. Furthermore, to understand cellular mechanisms, versatile means for altering the environment conditions and for stimulating and measuring the cellular responses both at a cell and at a population level are needed. In order to increase the sensitivity, repeatability, reliability, information contents and cost-efficiency of the scientific cellular experiments, our group develops automatic systems for cell cultivation, cell stimulation and cell response characterization using micro- and nanotechnologies.

This presentation describes general trends in in-vitro cell assays and their applications and illustrates our activities. Examples are given on microfluidic cell perfusion and gas supply, electromechanical cell stimulation and measurement, and biochemical cell stimulation using novel microrobotic cell injection. The application examples include studies on the influences of the novel biomimetic microsystem environments on the proliferation and signalling of human neuronal and cardiac cells.

Biomimetic Marine Propulsion

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Abstract

Biological systems have not developed an axle and wheel rotating system, except at molecular levels. This necessitated the development of oscillating and jetting systems to produce the transfer of momentum required for motion in water.

The principles of hydro-jet propulsion, and finned propulsion will be discussed and applications to surface and underwater vehicles will be presented, including an analysis of the reasons for the scarcity of practical biomimetic designs for propulsion .

The talk will start with gravity propulsion mechanisms (periodic gliding) and continue to comparison of periodic jet propulsion as compared to technological continuous jets. Next, applications of BCF swimming will be discussed and the effects of body motion compared to fin-only propulsion will be applied to biomimetic propulsion.

Finally, MPF swimming and paired fins, as control surfaces will be discussed.

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Bionic inspired fibres based materials

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Abstract

An intensive and interdisciplinary cooperation between natural scientists (e.g. biologists) and engineers/technicians is essential for a successful bionic research and development. Fibre based materials and technologies have a great potential for successful bionic developments, because there are different similarities to living nature:

Starting from small and smallest construction units bigger systems are build up.

Hairy structures by plants and animals are responsible for specific functions and mechanisms. Hairs can be found on the upper and under sides of insects, between the parts of an insect exoskeleton, in the feathers of birds, in the coats of animals, and in spiders' webs.

The use of fibre reinforcement is an essential tool in nature constructions for strong and in the same time lightweight materials and material extensive composites. Nature has many forms of fiber-reinforced materials.

Since 11 years at ITV Denkendorf in close cooperation to biologists an intensive bionic research and development is used. Based on selected examples the technical transfer into industrial products will be shown.

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Bionics for Mechatronic Applications

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Abstract

The success of biological organisms in solving problems encountered in their environments is attributed to the process of natural selection, whose primary metric is survival. Biological solutions offer insights into alternative strategies for designing engineering robotic systems. Looking at nature, engineers can find a huge database of biologically-inspired solutions to problems. There is thus much that engineers can learn from biology and emulate in their design of engineering systems. Bionics involves 'reverse engineering' the principles of evolutionary design of biological organisms in order to implement biological solutions to general engineering problems. The problems encountered by biological systems are similar in many respects to those encountered in engineered systems; it seems appropriate therefore to examine biological solutions in order to analyse engineering issues. Research efforts in this direction have recently become significant in interdisciplinary-engineering areas such as mechatronics and robotics. In this talk, motivation and potential benefits of a bio-inspired approach are addressed and an attempt to define a bionic methodology for robotic design is investigated through the analysis of novel bio-inspired engineering projects.

Control of Nonlinear Dynamic Systems Using Biologically Inspired Inexpensive Memory-Based Approach

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Abstract

One of the most challenge issues for control engineering is the omnipresent uncertainties in nonlinear dynamic systems. Traditionally, PID-type control has been widely used due to its simplicity in structure and easy implementation. However, such method is applicable to linear systems and it is usually difficult to determine the three control gains in practice – typically determined by experience or some heuristics methods (e.g., the Zeigler-Nichols tuning rules).

Various nonlinear control methods such as inverse dynamics control (feedback linearization control), Lyapunov redesign, sliding mode control, backstepping control, and nonlinear adaptive control have been proposed to copy with system nonlinearities and uncertainties. These methods, however, either demand significant on-line computation or involve complicated design procedures.

In this work, we explore a memory-based control method for nonlinear dynamic systems with significant nonlinearities, modeling uncertainties and external disturbances. Memory is one of the most intriguing biological units of human beings, which is what makes possible so many of our complex cognitive functions. This work makes use of short-term memory to build control algorithms for dynamic systems without detail system model information. The fundamental idea behind this method is to use certain sensor information (i.e., current tracking error, most recent tracking errors, and previous control experiences) to generate new control commands. The way that the memory-based control deals with system nonlinearities and uncertainties is essentially different from traditional control methods - there is no need for detailed information on external disturbances and uncertainties. Furthermore, it does not involve redesign or re-program the control scheme even if the system operation conditions change. The salient feature of the proposed approach also lies in its simplicity in design and implementation. The overall computation involved in this bio-inspired control is much less than most other methods thus can be realized straightforwardly and inexpensively. Both theoretical analysis and application (to formation control of multiple unmanned ground vehicles) confirm the effectiveness of the method.

Forced impalement of liquids by drop impacts on surfaces madehydrophobic by a biomimetic process

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Abstract

We report experiments of drop impacts on different micro or nanofactured substrates in order to study the impalement of liquids. The first kind of surface consists of a silicon substrate covered by a carpet of nanowires inspired by a biomimetic approach and chemically coated with a low surface energy fluoropolymer. The micro-structure of the surface is similar to some biological superhydrophobic surface(Lotus leaf for example)[1,2]. The contact angle is close to 160 degrees, with very small hysteresis.

The situation is very similar to that of a drop impacting a hot smooth plate - the so-called Leidenfrost effect. Nevertheless, wheras in Leidenfrost situation the impact velocity could not exceed a certain value in order to avoid the break of the vapour film, here the impact velocity can be increased until a limit beyond which the drop is impaled into the nanowire carpet. In absence of impalement, after the drop hits the surface, it experiences a flattening phase due to its initial inertia, taking the shape of a pancake.

Once it reaches its maximal lateral expansion, the drop begins to retract and bounces back. We have extracted the lateral extension of the drop, and we propose a model that explains the trend[3]. We also measured the limit initial velocity beyond which the drop is impaled into the nanowire carpet, and it turns out that the nano-scale and high aspect ratio of the wires provide a very high resistance to impalement.

The second kind of surface is a hydrophobic micro-grid, of typical spacing 50 _m used for studiying the impalement in a more fundamental point of view. Different impact configurations were tested. We found a threshold in impact speed above which a small amount of liquid protrudes the grid and emerges to the other side. For small grid spacings, the emerging liquid takes the form of micro-droplets which size is about the size of the grid step leading to method to produce either a mono-disperse spray or a single tiny droplet of sub-nanoliter volume. We propose some attempts of theoretical explanations for various[4].

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Nanoparticle-Coated Microtubes for the Manipulation of Cancer Cells

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Abstract

Formation of metastases by invasive transformed cells accounts for approximately 90% of all deaths in cancer patients. Our laboratory has developed new methods for the isolation of intact, viable cancer cells from patient blood samples, based on the physiological adhesion of selectin proteins in microscale flow devices. These cells can be maintained in culture for further study or drug screening, representing an exciting enabling technology for cancer research and treatment. More recently, we have found that monolayer coatings of colloidal nanoparticles, or naturally-forming halloysite nanotubes, can greatly improve the efficiency of cell capture and selective isolation of rare cell populations under flow. In related work, we have developed novel procedures for the packaging of siRNA genetic material into nanoscale liposomes, functionalizing the surface of these nanoparticles with biological adhesion molecules such as selectins, and then coating the interior surface of flow channels with this construct. When cells are perfused through the resulting device, e.g., blood or cancer cells, the targeted cells stick and roll on the device surface, take up the nanocapsules, and then ingest the genetic materials. In this manner, we have demonstrated effective gene delivery and targeted gene silencing in circulating cancer cells.

Nature as a Library of Materials, Structures, Principles and Laws with Potential Biomimetic Application in Bioengineering and Medicine

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Abstract

Due to the fact that many researchers and technicians are searching for the answers to the enigma of animals' and plants' bodies as their inspiration sources for the creation of new materials and structures, the biomimetics appeared. This is the border between old and new, the starting point in developing of new branches of applied science. The domain of biological materials and natural systems is large, representing an interdisciplinary theme comprising biomaterials' science, biomechanics, bioengineering, engineering combined with biology and medicine. The art and the science of designing, projecting and building biomimetics devices is called biomimetics and sums a number of areas of scientific and applied interest like: nanotechnologies, medical-surgical prosthesis and medical industry (antibodies and nanorobotic universal blood substitutes, artificial organs, artificial limbs, various electronic devices a.s.o.), robotics, artificial intelligence, defence industry (visualizing devices on various wave-lengths, listening devices, signal amplifiers, navigation systems, data converters) a.s.o.

Negotiating Complex Terrain: What Must We Understand to Develop Truly Animal-like Robots?

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Abstract

Over the past several decades considerable effort has gone into using animal locomotion to guide robotic design in an attempt to achieve vehicles that capture animal agility. Although progress has been made, most of today's robots still fall short of this goal. At least part of the reason for this shortfall stems from the fact that biological studies have only scratched the surface of locomotion properties that guide animals as they negotiate complex terrain. The focus has been on better muscle-like actuators, leg design, sensors attachment devices and control leading to stability on horizontal surfaces or vertical walls. As important as these factors are, much of the biological control properties that lead to truly animal-like movement through natural environments lies in the central nervous system, especially in brain circuits. Consider your own daily movements. You sit at your desk and then realize that you are hungry. There is a restaurant down the street that your memory banks say can provide you with a satisfying meal. You stand up and walk toward your office door. When you get there you open the door and move through, go to the stairs, change your gait to climb down the stairs and then negotiate yet another door. All of these actions are goal directed, not trial-and-error. Once outside you turn toward the restaurant and negotiate all the barriers in your path to arrive at your goal and satisfy your hunger. This simple trip requires numerous changes in gait, turns stair climbing and goal directed movement. Barriers require that you choose appropriate strategies to get around objects and then re-acquire your goal. All these actions are supervised by brain circuits that utilize massive amounts of sensory information both from within your body and from the surrounding environment to alter basic walking patterns on a step-by-step fashion. Unless we can understand how these modifications are carried out, we will never achieve our goal of animal-like vehicles.

This realization led us to study movement of an agile insect, the cockroach, as it negotiates barriers. All of our studies are grounded in behavior. We quantified decision points as the cockroach deals with barriers such as blocks and shelves. The blocks are tall enough to force the insect to alter its posture before climbing. It does this by first evaluating the height of the block with antennae, rearing up and then accurately placing its front legs on top. A shelf provides a larger problem. The insect can now either climb over or tunnel under the object. Again this decision is guided by antennal contact, but is influenced by ambient light conditions. In bright light, the cockroach is pre-disposed to tunnel to avoid

the light. The multi-sensory nature of these behaviors suggests that integration in a brain region such as the central complex may be involved. The central complex is a group of midline neuropils in the brains of all insects that have been implemented in these kinds of decisions. Lesions within the central complex affect specific behaviors and recordings in these neuropils show that many sensory cues (including vision and antennal inputs) are processed there. Non-linear processing of multiple sensory cues occurs in the central complex. Using a tethered preparation, we demonstrated that neurons within the central complex change their activity rate as the cockroach alters step frequency. Indeed, some of these neurons alter their firing rate before the cockroach changes step frequency, suggesting that they may be involved in formulating commands to alter ongoing movement.

We believe that an understanding of how brain circuits in the central complex process sensory information and then use the resulting information to re-direct leg movements is critical to development of animal-like autonomy. We are, therefore, working with engineers in Dr. Roger Quinn's biorobotics laboratory to capture the properties that we are studying in systems that control their robots.

On The Formation of Regular Patterns from Drying Droplets and their Potential Use for Bio-medical Applications

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Abstract

Droplet evaporation is of great importance in many wide ranging areas, such as spray cooling, thin film coating, detergency, as well as in biological areas such as DNA stretching. Colloidal deposition is also used to produce nanocrystals. The evaporation of colloidal suspensions can also be used to produce precise patterns such as in bioassays. The resultant deposit patterns left after complete evaporation can be quite varied and complex and attempts to control the flow in sessile liquid droplets have so far proven to be difficult. It is well known that during the evaporation of a colloidal suspension, particles are drawn to the drop periphery. This accumulation leads to what is known as the coffee ring effect, where rings of dried particles are left after complete evaporation. Surface tension gradients (Marangoni effects), internal convection, conduction through the substrate, temperature effects of fluid, substrate, and ambient vapour, mass transfer through diffusion, and various other factors, such as electrostatic attraction between the particles and substrate, all combine to complicate the process of colloidal drop evaporation.

In this paper we present the results of an experimental investigation of the evaporation and dryout of nanofluid solutions. The patterns formed are investigated and their dependence on operating conditions is evidenced. These patterns could be related to the dryout of biological fluids, like serum and blood.

Indeed, this could be a step towards the determination of the relationship between the pathological processes occurring in an organism, the variation of the physical and physicochemical properties of the biological fluids caused by these processes, and the morphology of the patterns produced in drying of sessile droplets of such fluids. Not only are morphological characteristics of blood elements known to change due to diseases, but also its biochemical composition. The biochemical analysis of blood, however, is rather time-consuming and labour-intensive. It may be possible to exploit the fact that the evaporation of blood serum (plasma) is found to leave behind a protein film with complex stain morphologies. These stains have distinguishable attributes based on the original serum composition and this has implications for the possibility of use in medical diagnosis. However, there is at present a lack of adequate research being carried out into this serum stain analysis technique.

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Recent advancement in mimicking and controlling a beetle, *Allomyrina Dichotoma*

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Abstract

In this work, we reports our recent advancement in mimicking a beetle, *Allomyrina Dichotoma*, as an effort to mimic various aspects of the beetle in near future. Features of beetles in terms of flight parameter and wing folding/unfolding mechanism are first reported, followed by design and evaluation of an artificial foldable wing and a small size motor-driven flapper. Folding and unfolding of the hind wing were triggered by electrically-activated shape memory alloy (SMA) wires. In addition, we have introduced a motor-driven flapping-wing system that can create a large flapping angle like a beetle. The passive wing rotation was implemented into the flapper by means of flexible members. Hover capability of the flapping-wing system is also demonstrated. This talk also includes recent progress in controlling the beetle by directly inserting wire- electrodes into the brain. We report the beetle's flapping wing response to various electric signals into the brain.

Soil Adhesion, Friction and Bionics

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Abstract

Experiences over the past have proved that a lot of energy used in agricultural cultivation is consumed generally during primary tillage. Soil is complex material and its behavior is transient and changes based on soil state. One of the most important components causing higher energy consumption during manipulation of soil by cultivation implements is soil adhesion and friction between soil and interacting parts of the equipment or tools. This presentation elaborates some the basics of soil adhesions and friction, and their influence on soil forces acting on tillage tools. It gives details of various researches carried out in the past to reduce their influence on forces at soil-tine interface by manipulating tool surfaces. Bionics has been successfully used to manipulate the tool surfaces. It also reviews the various efforts carried out by the scientists working on this topic in different parts of the globe. Emphasis was given to explain how the properties of soil animals can be used to reduce the friction and adhesion at soil-tool interface.

Detailed experimental data are presented of a study conducted to study the effect of modified surfaces on the soil-tool interaction. For this flat plates and a mold board plough was used. The surface characteristics were altered by using different geometric surfaces on the surfaces interacting with the soil. Results showed that by altering the surface morphology, it is possible to reduce soil forces acting on the tool surface. Specific examples are given to elaborate use of bionics in agricultural research. There is need for increased efforts to use principles of Mother Nature for specific applications, including agriculture.

Structural biological materials: Fascinating insights into the structure of life

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Abstract

The study of materials that have evolved through millions of years of evolution and natural selection can provide insights into heretofore-unexploited mechanisms of toughening. Structural biological materials such as mollusk shells, bones and teeth have hierarchical assembly from the nanoscale to the macroscale. Other defining features are multifunctionality, self-assembly under ambient conditions and adaptability. Most biological systems are grown through a bottom-up strategy, in contrast with conventional synthesis methods, which have been mainly top-down manufacturing methods. These materials are lightweight with densities<3gm/cm^3 and are composed of a limited number of elements, yielding specific strengths, elastic modulus and toughness values that are extraordinarily high. These provide a new paradigm as the basis for bioinspired materials design.

This talk will broadly cover research on structural biological materials. Mollusk shells, bones and antlers, teeth and tusks, horns, arthropod exoskeletons and avian feathers and beaks will be discussed and parallels will be drawn. The emphasis will be on the quasi-static and dynamic mechanical properties (tension, compression, shear and bending testing) and microstructural features that act to enhance the properties. Microstructural features such as selective porosity, porosity gradients, biopolymer/mineral interaction and the presence of fibrous proteins or polysaccharides all act to toughen the materials.

The processes of biomineralization involve the secretion of proteins, and complex supramolecular protein structures, along with other biopolymers such as polysaccharides and genetic messages. Biomineralization of mollusk shells and demineralization/deproteinization of bone will be discussed.

Joanna McKittrick is a Professor of Materials Science and Engineering in the Department of Mechanical and Aerospace Engineering at UC San Diego since 1988. She holds a B.S. in Mechanical Engineering from the University of Colorado, a M.S. in Materials Science and Engineering from Northwestern University and a Ph.D. from MIT. She has been a Visiting Scientist at the Los Alamos National Laboratory in the Polymer and Coatings Group and a Program Manager at the National Science Foundation in the Division of Materials Research. She has worked on rapid solidification, zeolite processing, thin film ferroelectrics and luminescence properties. Her current research interests include structural biological materials, biomineralization, biomimetic processing, powder synthesis and luminescence properties of oxides and nitrides.

Wetting behaviours of a single droplet on biomimetic micro structured surfaces

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Abstract

Wettability as a surface property, which plays important roles in a variety of industrial areas such as textile, coating, micro fluidics and tribology has become an important topic of biomimetic functional surfaces study. Surface wetting properties also play important roles in boiling and condensation. Natural surfaces with super hydrophobic properties often have micro or hierarchical structures. In this paper, the wetting behaviours of a single droplet on biomimetic micro structured surfaces with different roughness parameters are investigated. A theoretical model is proposed to study wetting transitions. The results of theoretical analysis are compared with those of experiment indicating that the proposed model can effectively predict the wetting transition. Furthermore, a numerical simulation based on the messo scale lattice Boltzmann method (LBM) is performed to study dynamic contact angles, contact lines, and local velocity fields for the case that a droplet displays on the micro structured surface.

Bio-Inspired, Smart, Multiscale Interfacial Materials

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Abstract

Bio-inspired smart materials should be a "live" material with various functions like organism in Nature, they must have three essential elements which are sense, drive and control. The studies on lotus and rice leaves reveal that a super-hydrophobic surface with both a large CA and small sliding angle relies on micro- and nanostructures. Considering the arrangement of the micro- and nanostructures, the surface structures of the water-strider's legs were studied in detail. Accordingly, super-hydrophobic surfaces of aligned carbon nanotube films, aligned polymer nanofibers and differently patterned aligned carbon nanotube films were fabricated. The large scale fabrications of super-hydrophobic polymer surfaces were developed by modification of the traditional template method, the adoption of one-step coating and electrohydrodynamic processes respectively. Many methods had been applied in making superhydrophobic films with multi-functional properties, such as structural colored, transparent and/or conductive superhydrophobic films. Under certain circumstances, a surface wettability can switch between superhydrophilicity and superhydrophobicity, just like in Chinese ancient Taiji philosophy that "Yin" and "Yang", the two opposing fundamental properties of nature, are switchable. The interaction between surface micro- and nanostructures and surface modification of poly (*N*-isopropylacrylamide) gave reversible switching. By grafting the copolymer of temperature-sensitive and pH-sensitive components, a dual-responsive surface which can be controlled by either or both temperature and pH was fabricated. Besides organic surfaces, a series of inorganic switches were also made. UV light stimulated transition between superhydrophobic and superhydrophilic by aligned ZnO, TiO_2, and SnO_2 films were successfully prepared respectively. A dual-responsive WO_3 film with controlled wetting and Photochromism was obtained by an inexpensive and simple electrochemical deposition process. Most recently, we discovered the water

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collection ability of capture silk of the cribellate spider Uloborus walckenaerius and we also developed a superoleophobic and low adhesive water/solid interface which opens up a new strategy to control self-cleaning properties, facilitating the introduction of oleophobic properties to common substrates. In addition, we developed the novel biomimetic ion channel systems. These studies have great application potentials in the fields of integrated micro-electronic devices, microfluidic control, trace bioanalysis and smart functional windows, etc.

Wettability Distribution Effects on Water Flooding Problems in a PEM Fuel Cell

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Abstract

It is well-known that water flooding problems in the gas diffusion layer (GDL) and its adjacent gas microchannels of a PEM fuel cell would cause a drastic deterioration of its performance. For this reason, a great deal of efforts have recently been devoted to study the reduction of water flooding problems by changing wettabilities of pores in the gas diffusion layer and the surface of the microchannel. In this paper, the free-energy model of the two-phase/two-component lattice Boltzmann method (LBM) is applied to simulate water transport in the gas diffusion layer and its adjacent microchannels of a PEM fuel cell. The microstructure of the carbon paper GDL is first reconstructed by a stochastic method. Effects of pore wettability distribution in the carbon paper GDL on water droplets formation and transport, and their subsequent movement in the adjacent gas microchannels under the action of gas flow are simulated. A simplified analytical solution on the dynamic behavior of water droplet removal in the microchannel is presented, and the effect of the gas flow velocity and the wettability of the microchannel on droplet detachment size are compared with the LBM numerical simulation. It is found that suitable modifications of pore wettability distribution in the gas diffusion layer and the microchannel of a PEM fuel cell will facilitate water transport, and thus preventing flooding to occur in the fuel cell.

Session1: Functional Bionics/Biomimetics

A Novel Method for 3D-Segmentation of Vascular Images

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Abstract

Constructing an accurate digital model of vessel networks is critical to vascular tissue engineering, in which the segmentation of vessel plays an important role. However, the existing segmentation methods are not able to achieve the goal of accurate segmentation of vessel networks. This paper presents the development of a method for vessel segmentation based on a data structure of octree and 3D region growing. Firstly, the volume data of vessel images are divided into different data groups according to the predetermined depth value of octree, and then the optimal slices sequence is defined by analyzing the octree's nodes which contain the vessel region. Then, the vessel segmentation is conducted from the vessels images of octree nodes based on 3D region growing. Finally, the treated data blocks are reset and the segmentation results of the whole volume data are obtained. By applying this method to the volume data of vascular images from MRA, accurate vessel segmentation results are achieved. This work would represent a significant advance for digital modeling of vessel networks.

Keywords: Vascular tissue engineering, Image segmentation, Region growing, Octree

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Bionic Design of the Surface Morphology of Rubber BushCovered on Driving Drums

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Abstract

Driving drum uses friction force to transfer power in belt conveyor. By means of bionic technology, the surface morphology of driving drum's flexible cladding was researched to increase the frictional traction force in this paper. Taking tree frog and katydid as biological prototypes, the structural features and adhesion mechanism of their epidermal pad attachment organs were studied. Imitating the shape and structure of the epidermal pads based on the principle of function bionics, four new surface morphologies of drum's bush were designed. The contact behavior of the bionic bush and the belt was simulated with finite element analysis software. The results of contact analysis showed that the bionic drum's bushes could generate embedding and interlocking effect during the contact process. The contact form could be changed from plane or cambered surface to meshing contact to enhance the frictional traction of drums.

Keywords: Epidermal pad, Surface morphology, Bionic design, Finite element analysis, Friction

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Effects of Egg White Protein on Calcium Carbonate Crystalline

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Abstract

Calcium carbonate was synthesized in egg white protein solution by using calcium chloride and sodium carbonate as reagents. Effects of different concentrations of egg white protein on the calcium carbonate crystal growth were studied. The morphology and structure of the calcium carbonate are characterized by scanning electron microscopic (SEM) and Fourier transform infrared spectroscopy (FT-IR) and powder X-ray diffraction (XRD). The thermal property of calcium carbonate was studied by thermal analyzer (TG). The results showed that the concentration of egg white protein had great influence on the shape and orientation of calcium carbonate crystal. The synthesized sample was egg white protein-$CaCO_3$ compound with a sphere crystal, which was different from the one formed in pure water. The study indicated that the coordination and the electrostatic interaction of egg white protein and the Ca^{2+} ions played important roles in affecting the calcium carbonate crystal.

Keywords: Egg white protein, Spherical calcium carbonate, Vaterite, Calcite

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Helicoidal Round-Hole Fiber Distribution of Tumble Elytra and Extrusion Strength of Biomimetically Holed Composite

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Abstract

Scanning electron microscope (SEM) observation shows that Tumble bug elytra consists of parallel cuticles, which is a kind of chitin-fiber-reinforced biocomposite. In the biocomposite, the chitin fibers distribute in a helicoidal pattern. The observation also shows that there are many holes in the cuticles which allow biological pillars uprightly pass through them. More careful observation shows that the chitin fibers near these holes helicoidally round these holes forming a kind of helicoidal round-hole fiber distribution. Based on the observation, a kind of molding hole of the composite with the helicoidal round-hole fiber distribution was biomimetically fabricated with a special mould. The extrusion strength of the molding hole was investigated and compared with that of drilling hole. It shows that the extrusion strength of the molding hole is markedly larger than that of the drilling hole.

Keywords: Tumble bug elytra, Helicoidal round-hole distribution, Biomimetical fabrication, Molding hole, Extrusion strength

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Primary Research on Bionic Design of Multi-Surface Solar Concentrator Based on the Flower Structure

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Abstract

Plants can not grow and reproduce without sunshine. Flowers have an inseparable relationship with sunshine. Most studies on the relationship of the plant and sunshine focus on the influence that sunshine has on plants, such as photosynthesis. However, not much has been done on the relationship between flower structure and sunshine. Through observation and comparison, the outlines of many flower contours have some similarities with the solar concentrator. This paper delves into the relation between flower structure and light, in order to get the new ideas of designing solar concentrator. By means of extracting a contour line of flowers, their geometric structure models are got. Through simulation calculations of optical software, light-gathering performance of flowers is researched with respect to different incident angle. Then based on researching the light-gathering process of the flowers, the innovative design ideas of bionic solar concentrators with excellent performance are presented. So in this way traditional thinking mode of single curve or surface used in solar concentrator design is expanded.

Keywords: Flowers, Bionic, Solar concentrator

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Study on the Shrinkage Error of Similar Material by Simulation Experiment

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Abstract

Shrinkage error will impact the results obtained from the observation data when studying subsidence by the method of similar material simulation experiment. Using digital industrial close-range photogrammetry system in the experiment, high-precision observational data is collected. By comparative analysis on the subsidence of the points at different locations, we obtained the distribution law of shrinkage subsidence and horizontal movement which has great significance for the study on how to reduce the shrinkage error effectively.

Keywords: Subsidence, Shrinkage error, Similar material simulation experiment, Digital industrial close-Range photogrammetry system

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Development of a Distribution System for Measuring Nozzle Integrative Parameters

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Abstract

The experimental system used was equipped with sensors and computer-controlled processing technology. This system was used in the measurement of major performance parameters such as pressure, flux, spray angle, spray distribution character of the nozzle and its integrative performance parameter. It could also achieve precise and synchronous measurements, and process multi parameters. Measuring position of a single nozzle was also available for three-dimensional adjustment by nozzle transmission frame. The boom could achieve two-dimensional precision adjustment. Fluid power supply system could ensure the accurate measurement of nozzle flow between 50~15000ml/min. The control system consisted of a PC, a CCD image acquisition system, data acquisition cards, sensors, and single chip microcomputer. The spray angle was measured by image processing technique. Data fusion technology was used to improve the precise measurement of spray angle. Neural network technology was used to improve the precision and speed of the system. The results showed that it is promising for using this system for measuring nozzle integrative parameter is promising.

Keywords: Nozzle, Performance test, Image processing, Neural network

Influence of the Optical Multi-Film Thickness on the Saturation of the Structural Color Displayed

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Abstract

In this paper, it is demonstrated that saturation of the structure color exhibited by the multi-film systems can be determined by the thickness parameter of the multi-films. The multi-film of 1-quarter film system and 3-quarter film system with the central wavelength of 650nm, exhibiting the color red, are fabricated by deposition method, to prove this principle. Simulation was done based on the light interference principle, and experiment results both show that the reflective spectra of the 1-quarter film system have wider bandwidth. Saturations of the color from different systems are calculated separately by the CIE colorimetry method, to prove that the 3-quarter film system produces colors with higher saturation.

Keywords: Saturation, Structural color, Multi-film, Thin film thickness, Interference principle

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Light Harvesting Mechanism of Photosystem II in Photosynthesis and Its Inspiration for Photoinitiators

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Abstract

As one of the most important chemical reactions on earth, the photosynthetic reaction has gained much attention. For example, the Foliage and algae possess preeminent abilities to harvest luminous energy from sunlight in photosynthetic reactions by capturing light with the light-harvesting complex (LHC) and transferring the energy from LHC to the reaction center (RC) in Photosystem II (PSII), to realize the continuous and efficient transformation from luminous energy to chemistry energy. In this article, the progress in the studies on the crystal structure of PSII, the energy and electron transfer mechanism, and artificial simulation on photo-induced electron transfer are reviewed. Additionally, the initiating mechanism of hydrogen-abstraction photoinitiators, and the inspiration of the principles and mechanisms of photo-induced electron transfer in macromolecular photoinitiators were also discussed. It is believed that choosing covalent chains of appropriate types and length as the bridge between electron donor and electron acceptor is crucial for improving the initiating efficiency of photoinitiators.

Keywords: Photosynthesis, Photosystem, Light harvesting, Photoinitiator, Electron transfer

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A Finite Element Modeling of a Beetle Wing

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Abstract

Numerical simulation plays a very important role in understanding the behaviors of insect flight. In this study, a method to build a finite element model has been proposed based on the real beetle wing which was 50 mm long in spanwise direction and 20 mm long in chordwise direction. We scanned the real beetle wing with a scanner to get its two dimensional image. The scanned image was used to make a CAD data of membrane and vein's outer lines. Those lines were used to build a finite element model. The model was divided into 48 regions so that thickness variation of membranes and veins could be taken into account. The effect of vein's cross section on the accuracy of the finite element model was investigated. The finite element model simulated a bending test of a real beetle wing and the analysis results agreed with experimental ones well.

Keywords: Beetle wing, Elastic modulus, Bending test, Finite element modeling

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A New Face Detection Method in Colour Images Using Skin Colour Model and Eye Detection Method

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Abstract

In this paper, a face detection method is proposed for identifying any human faces in colour images using human skin model and eye detection method. Firstly, this method can be used to detect skin regions from the input colour image after normalizing its luminance. Then, all face candidates are identified using an eye detection method. Comparing with existing algorithms, this method only relies on the colour and geometrical data of human face rather than using training datasets. From experimental results, it has been shown that this method is effective and fast.

Keywords: Face detection, Skin colour model, Eye detection, Bio-robots

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A Preliminary Study of the Structure and Architecture of Walnut Shell

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Abstract

Shell-type structures can be found almost everywhere especially in natural forms with examples that include egg shells, turtle shells, nuts, animal skulls, tiny living cells, seashells and crustaceans. Nuts are good examples of nature covering the central part of the fruit with a dome-shaped shell, which is resistant against compression. The shell design of a walnut seems to be designed to resist fracture by external forces. Nature, through adaptivity in the form of natural selection, has improved structural attributes. In this preliminary study, the walnut shell was studied under different loads to derive the optimized loading behavior of the shell. This new data on the behavior of walnut shell under different loading conditions besides theoretical examples proposes walnut shell as an appropriate choice for further studies on designing an optimized shell under point load or cylindrical shells with interior partitions under dynamic loads. Further studies by the use of pre-optimized walnut shell structure in connection with construction software and FE programs will save time and money and offers more flexibility to designers and product engineers in the shell and spatial structure designing field.

Keywords: Walnut shell, Shell, Point load, Parabolic arch, Cylindrical shells, Architecture

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A Study of the Velocity Field during Evaporation of Sessile Water and Water/Ethanol Drops

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Abstract

Many studies have investigated evaporation of sessile drops in an attempt to understand the effect of wetting on the evaporation process. Recently interest has also increased in the deposition of particles from such drops, with evaporative mass flux being deemed to be responsible for ring-like deposits, and counteraction of the mass flux by Marangoni convection explaining more uniform deposition patterns. Understanding of such deposition processes is important in biological applications, such as the Litos test-system endorsed by the Russian Ministry of Health for diagnosis of urolithiasis and the evaporation of colloidal drops for depositing and organizing proteins and DNA. In most cases where deposition from evaporating drops has been studied, velocity information is inferred from the final deposition pattern or from mathematical modeling based on simplified models of the physics of the evaporation process. In this study we have directly measured the flow velocities in the base of sessile drops, using micro-PIV, viewing the drop from below, through the cover slide.

For water drops, a radial pattern of flow was observed with a maximum velocity close to but not at the pinned outer edge. For 'azeotropic' ethanol/water mixtures, the velocity field is more chaotic to begin with, passing through a phase involving three or four recirculation cells and finally having the same radial pattern as for water drops.

Keywords: Evaporation, Sessile drop, Velocimetry, Particle deposition, μPIV

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Evaluation of Cardiovascular Stress Reaction Using Hpcd Method on a Beat-By-Beat Basis

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Abstract

In order to establish a bionic model/system in cardiovascular fields, comprehension of hemodynamics is important. In this study, a novel beat-by-beat hemodynamic system evaluation method named "beat-by-beat HPCD method" is proposed and evaluated. Gregg's theoretically driven model of hemodynamics which was called "HPCD method" is improved by using non-invasive and beat-by-beat cardiovascular measurement of mean blood pressure (MBP) and cardiac output (CO). Continuous beat-by-beat measurements of MBP and CO were done on three healthy male subjects during three hours. In the measurement, a five minutes cold pressor test was executed in each subject and also each subject done exercise using a bicycle ergometer in five minutes and walked during 15 minutes. Measured beat-by-beat MBP and CO can derive beat-by-beat HP (hemodynamic profile) and CD (compensation deficit). Then, beat-by-beat changes are clearly observed from plots on HP axis and CD axis plane. More vascular response can be observed on cold pressor and more myocardial response can be observed on ergometer exercise. During walking period, the response is intermediate between cold pressor and ergometer exercise. Finally, the proposed method can be considered as applicable to evaluate cardiovascular bionic system especially on evaluation of a person being subjected to stress.

Keywords: Hemodynamics, Stress, Cardiovascular system, Hemodynamic profile and compensation deficit model

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The Techniques of Reducing Adhesion and Scouring Soil by Bionic – Review of Literature

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Abstract

Soil adhesion is a complicated multiple phase system influenced by many factors such as soil type, soil moisture content, contact material characteristics, working speed and external forces and environment. Adhesion of soil on the surfaces of soil-engaging components of various machines and equipment affects the quality of the work and in extreme cases; it does not allow the machine to move in moist sticky soil conditions. Moreover, adhesion of soil on the surfaces of ground engaging components of various machines and equipment increases the draft and energy consumption of these machines. Different techniques are employed to reduce adhesion of soil to the surfaces of these machines and equipment. This paper reviews some of the common techniques employed in reducing adhesion and scouring soil from the surface of agricultural machinery and equipment. It reviews the advantages and disadvantages of using these techniques and their limitations in practical field conditions. An ideal technique should be safe and simple, economical to manufacture, easy to use, synchronise with other components of the machine and tools, no requirement for extra controls and power, less energy consuming and efficient with scouring abilities 90% or higher. Some techniques such as air injection is useful but it adds on weight to the existing set up and in many cases makes the system more complicated to operate. Enamel coating is cheap and comparatively simple technique for reducing adhesion. It has poor wear resistance and cannot be used in abrasive soil conditions. The soil adhesion preventing mechanism of soil animal's cuticles addresses some of these issues. The surface characteristics of soil animal's cuticles have excellent scouring abilities and may be applied on the surfaces of soil engaging components of tillage tools. Ultra High Molecular Weight-Polyethylene (UHMW-PE) has better scouring characteristics and wears resistance. This could be applied for bionic modification of the surfaces of these tools for reducing adhesion and improving performance of a number of machines and equipment in sticky soil conditions.

Keywords: Adhesion, Bionic, Soil, Osmotic, Vibration, Lubrication

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The Role of Elytra in Beetle Flight: Quasi-Static Aerodynamic Forces Generation

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Abstract

In this paper, we have conducted a comprehensive study including wind-tunnel experimental evidences and three-dimension computational fluid dynamics simulation by using ANSYS-CFX software to investigate the aerodynamic characteristics of the elytra of a beetle, *Allomyrina dichotoma*. Our first approach is a quasi-static study by considering the effect of induced flow due to the flapping motion of the elytra at around 30~40 Hz flapping frequency and by varying the dihedral angle to represent its flapping angle during upstroke and downstroke. We found that an elytron produces positive lift at the 0° *g-AoA*, negative lift during upstroke, and always produces drag during upstroke and downstroke. We also found that the highest lift coefficient of an elytron is 1.5 produced at 45° *g-AoA* (by experiment) and 1.0 at 30° *g-AoA* (by simulation), while the highest drag coefficient is 3.5 at 30° *g-AoA* (by experiment) and 0.92 at 45° *g-AoA* (by experiment). The highest lift to drag ratio is 0.58 (by experiment) and 2.26 (by simulation) produced at 15° *g-AoA*. For a 10 g body weight of a beetle, the forewings (elytra) can produce lift around 4.42% (by simulation) or 1.3% (by experiment) and drag around 6.44% (by simulation) or 16.94% (by experiment) of its body weight.

Keywords: Elytra, Angle of attack, Dihedral angle, Lift, Drag, CFD, Wind-tunnel test

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Art Design from Direct Observation of Natural Objects

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Abstract

Natural systems are inspiration for concept design and architects explore design ideas by observing natural objects through drawings using computer-based technologies. Based on the achievements of our predecessors, the macroscopic of some natural objects were decoded, and the observations of integrated structures were interpreted with designers observing many forms of elements of a natural object from free-hand sketch and configurations of edge form aesthetics. The other bio-inspiration is to use 3D digitizing techniques to obtain surface geometrical, texture and colour information. The compositions and spatial gradients of multiple kinds of physical parameters, which included outline, shape, and surface, are summarized. In this paper the 2-D and 3-D nature objects were observed for aesthetics analysis of different types of shapes and forms. Then the art and design, and engineering methods were described with natural objects. Moreover, the surface feature data and 2D sketching were developed with the combination of segmentation, edge detection and 3D modelling rules. Finally, a method for product design by learning from nature and verves was proposed.

Keywords: Bio-inspiration, Design from nature, Design concept, Free-hand sketch, Form aesthetic

Establishing the Differential Constitutive Equation of Elytra Cuticle by Nanoindentation

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Abstract

Due to size limits in the transverse direction, tensile testing is not appropriate to investigate the mechanical properties of elytra cuticle of the dung beetle (*Copris ochus* Motschulsky). However, nanoindentation testing can determine a material's anisotropic properties through a single indentation. In the present study, nanoindentation stress–strain curves were used to characterize the complete mechanical behavior of dung beetle elytra cuticle. A differential constitutive equation has been developed with time-dependent spring constants k and viscosities η. To describe the complex viscoelastic behavior of dung beetle cuticle, a descriptive representation of the linear viscoelasticity law for the multilayer matrix has been formulated. A qualitative model for the relationship between cuticle structure and mechanical properties of elytra may help develop bionic composite materials for micro-aircraft, bionic tribology, bionic medical apparatus, and bionic organs (tissue engineering).

Keywords: Nanoindentation, Viscoelastic properties, Biomaterial

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Analysis on the Aerodynamic Characteristics of Bionic Wingspan Based on Frigate Bird Wing Structure

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Abstract

This paper extracts the frigate bird's leading edge contour by CATIA on the basis of the obverse and side pictures when frigate bird glides. Then three bionic wingspans bending upwards, forward and integration of the two using NACA 4412 airfoil. Compared with ordinary wingspan, the drag force of tested wingspan can be reduced, because the wingspan of bending forward can form airflow of S style which reduces the slope of the path-line of airflow and pressure reduction of the leading edge. And the working condition is improved by means of the bending forward wingspan which can reduce airflow's velocity. The lift efficiency of upward bending wingspan can be improved due to the fact that it can increase the leading edge's pressure which leads to high speed airflow.

Keywords: Leading edge contour, Bionic wingspans, NACA 4412, Aerodynamic performance

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Mechanical Character of Typica1 Plant Leaf Surfaces

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Abstract

The hardness of typical plant leaf surfaces was investigated and analyzed by nano-hardness tester. Results show that the mechanical character of varied texture and varied surface morphologies has regularity. The hardness of coriaceous fresh leaves (*Bambusa phyllostachys pubescens etc.*) and ligneous leaves is higher. Waxiness leaves′ hardness (such as *Nelumbo nucifera Gaertn, Canna indica Linn* (*generalis*) is lower. The hardness of convex morphology part is better than that of concave morphology part on non-smooth morphology of leaf surfaces. And that the hardness of surface layer is better than that of internal layer in the same leaf. This study can be an important biological foundation for design and fabrication of bionic engineering surface and composite materials.

Keywords: Engineering bionic, Plant leaf, Hardness, Mechanical character

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Visual Reconstruction and Feature Analysis of the Three-Dimensional Surface of Earthworm

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Abstract

This paper demonstrates a method for visual reconstruction and feature analysis of the three-dimensional surface of earthworm in CATIA (Computer Aided Three Dimensional Interactive Application) and IDL (Interactive Data Language). An earthworm with a relatively simple surface morphology and good capability in reducing soil adhesion and resistance was selected in order to study the feasible methods in the visual reconstruction and feature analysis of the three-dimensional surface of living things. The digital measurements of surfaces of the earthworm were carried out using a three-dimensional laser scanner. Point clouds, the scanning digital data of the surface of the earthworm, were processed by screening unwanted data, reconstructing surface and analysing feature in CATIA. In order to get more detailed information about the point clouds, IDL, which integrates a powerful, array-oriented language with numerous mathematical analysis and graphical display techniques, was adopted for the visual reconstruction and feature analysis of three- dimensional surface of the earthworm.

Importation of point clouds and reconstruction of the surface of earthworm were conducted in CATIA. Analysis feature of the scanning data and reconstructing surface were carried out in IDL, which provides a high level of flexibility to access, analyse and visualize the data using different methods. Polynomial regression equation of the surface of earthworm in the longitudinal plane was derived. In addition, point clouds were more easily displayed and analysed by resizing, rotating and zooming in IDL.

Methods and results presented in this paper prove to be potentially useful for analyzing the feature of biological prototype, optimizing the mathematical model and affording deformable physical model to bionic engineering, those works would have great implications to the research of biological coupling theory and technological creation in bionic engineering.

Keywords: Visual reconstruction, Feature analysis, Three-dimensional surface, Earthworm, CATIA, IDL

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A Bio-inspired Surface Modification to Improve Gas-Particle Erosion Resistance

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Abstract

Erosion by the impact of gas-particle flow is one of the important reasons which produce component failure. In order to improve erosion-wear resistance of wall, a bionic structure which is bio-inspired from desert lizard was designed according to the characteristics of boundary conditions on wall.

The improved k-ε turbulence model was adopted to build the mathematical models for the analysis of the particle trajectories, particle parameters and erosion mechanism. Particle erosion tests were conducted to verify the feasibility of the proposed method. The experimental results show that the proposed bio-inspired surface with dimple and convex structure can achieve anti-erosion rate of 16.4% and 12.2% respectively.

Keywords: Bionics, Bio-inspired surface, Erosion, Gas-particle flow, Boundary condition

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Efficiency Increase Research on Blade of Axial Fan Based on Characteristics of the Typical Birds' Wing

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Abstract

In the millions of years of evolution, the structure of birds' wing and the shape of the feather evolved to fly efficiently. When birds glide, the wave structure between the wing feathers plays a role in suppressing turbulence, reducing flow resistance, and increasing air flow velocity through the wing surface. The difference of the wave structure parameters between the upper and lower surface, increases velocity difference of the airflow through the upper and lower wing surface, hence flying lift is increased.

In this paper, eagle owl, sparrow hawk and buzzard were studied. The wave structure of wing and the shape of feather were quantized and used to make the blade of fan. The computer simulation analysis and aerodynamic experiments show that the efficiency of the bionic blade fan is remarkably higher than that of the prototype blade. The factors affecting the efficiency of the bionic blade are the wave structure distribution modes and parameters. In this paper the maximal efficiency increase of the bionic blade is 7.59%.

Keywords: Bionic coupling, Blade of axial fan, Efficiency increase

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Morphological Characteristics of the Wing Feather of the Owls for Silent Flight

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Abstract

Many species of owl, including the eagle owl, are known to be excellent nocturnal predators. Its prey, typically rodent animal, has acute hearing which can make up for the terrible vision at night. However, the owl in both gliding and flapping flight generates noise at low frequencies below prey's hearing range. Hence, the owl's flight to its prey is almost silent.

During millions of years of evolution, the wing feather of owl optimizes special characteristics which have functions of sound attenuation and absorption, such as the serration at the leading edge of the feather, the fringe at the trailing edge, and the velvet-like structure on the wing. Due to the above hush-kit, the noise emission of owl's flight can be controlled. The paper initiated a systematic morphology analysis of wing feather, and presented a quantitative comparison between the eagle owl and common buzzard. A variety of primary feathers taken from every specimen were investigated on macroscopic and microscopic level by stereomicroscope(SM) and scanning electron microscopy (SEM). The internal relationship between characteristic parameter of owl wing feather and silent flight was studied, and quantitative analysis of owl's hush-kit application can be prepared for the design of components in engineering.

Keywords: The eagle owl, Silent flight, Feather, Hush-kit

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Simulation of Wear Behavior of Pangolin Scale Configuration Based on Discrete Element Method

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Abstract

Pangolin scale configuration, which has the typical biological wear-resistant surface, was selected as the research object. The dynamic wear simulation system, which was composed of the arranged several Pangolin scales and the sand abrasive, was established based on Discrete Element Method (DEM). The simulation was performed under different velocities. From the dynamic wear morphology, the contact-bond fields, the contact-force fields and the velocity fields were simulated by DEM, at the same time, the fracture and the debris of the scale configuration were observed from microscopic and mesoscopic aspects. In addition to the local wear forces, the resistances of the whole scale configuration during the wear process were measured. The simulated results indicate that the Pangolin scale configuration has the best wear-resistant function when it is worn at the low velocities(less than 0.25m/s in DEM simulation). The wear extent becomes stable after the high degree wearing phase. The wear loss of the single scale configuration is 5.94%, 11.52% and 14.87% respectively under three velocities, which is in agreement with the soil abrasive wear test.

Keywords: Pangolin scale configuration, Biological wear-resistant surface, DEM simulation, Abrasive wear

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A biomimetic smart control of viscous drag reduction

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Abstract

Viscous flow drag represents the largest contingent of the entire drag that aerodynamic and hydrodynamic devices are subject to. Inspired by the functions of sharks skins, riblet surfaces have been studied and applied to wall structures to reduce turbulent flow drag. However, whilst structural similarity has been obtained it lacks true mimicry. This paper presents an approach of drag reduction using "Smart Surface", a new proposed composite surface that combines the riblet with an elastic coating. The "smart surface", inspired by the self-adjustable skin of marine animals such as the dolphin, is designed to modify the traditional riblet technique and enable it to "sense" and interact with the flow by adjusting the wall structure according to the flow condition. Considering the factors of manufacture feasibility, durability and drag reduction performance in previous studies, the physical model of "Smart Surface" is designed. The preliminary establishment of corresponding prediction model has been discussed and calculated. Further work in the aspects of experimental and numerical study of this research is prospected.

Key words: Drag reduction, Elastic coating, Riblet,, Self-adjustable, Smart Surface

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Optimize by Experimental Optimization Techniques on the Structure of the Corrugated Bionic Needle

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Abstract

Based on bionics, the study is about designing and optimizing the corrugated bionic needlebased on polynomial regression. A High-speed camera was used to capture the process of needle piercing into the fluid in order to analyze the mechanism of resistance reduction. The results showed that: the width of the ripple plays a major role in reducing resistance; nonsmooth structure of bionic needle reduces the contact area and the friction factor between needle and medium, and also the vortex was impaired.

Key Words: Bionics, Polynomial regression, Mechanism of resistance reduction

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Study of permeability function equation and stability analysis of the seepage field of unsaturated slope in the downstream yellow river levee

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Abstract

The triaxial test instrument for unsaturated soils controlled by stress and strain was used to measure the matric suction and volumetric water content of unsaturated soils, and a set of soil-water characteristic curves of silty clay were obtained. The equation of soil-water characteristic curve was also obtained by use of nonlinear curve fitting. The concrete form of the Mualem equation was deduced based on the relation between the soil-water characteristic curve equation and the permeability function equation. The results calculated by the concrete form of this Mualem equation are consistent with those measured by the direct method. The concrete form of the Mualem equation was further proved to be reasonable. Based on this, under the rain and flood conditions we used the finite element method to analyse the variability of the seepage field in the downstream yellow river levee which is a representative unsaturated slope. From this we got the extent of the influence of rain or flood infiltration in front of the phreatic line, which is about 2 meters. We analysed the combined influence of rain and flood infiltration and concluded that the influence of flood infiltration on the seepage field is determined by the amount of rainfall and duration of the rain.

Keywords: unsaturated soil, soil-water characteristic curve, permeability function, matric suction, finite element method

Study on bionic technology for Structures

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Abstract

In the 21st century, architects are facing problems of the natural resources and environment. People need beauty and adaptation, efficiency and energy saving, safety and economy, and the eco-architectures which meet the demand of sustainable development. If we could transfer the natural environment symbiosis strategies into construction strategies, architectures could dynamically adapt to the environment. If the architectures could, as biology, follow natural rule, it will not destroy natural environment but actually play a role in beautifying, enriching, regulating and improving natural environment. Therefore, bionics naturally becomes an important research direction for eco-architecture design. According to analysis on the existed research findings on ecology, bionics, eco-architecture theory and structure bionics, and considering the eco-architecture intensive objectives, the paper studied the basic theory of structure bionics first. Then taking animal and plant as prototype , and through pick-up of prototype structure systems, analysis of structure features and simulation of biodynamic characteristics, the principles and methods of eco-architecture structure bionics were studied. Finally, taking Shanghai Jinmao grand mansion and Beijing Olympics swimming stadium, the Water Cube, as examples, the structure was analyzed. Application of structure bionics in large public architecture design was explored. The present findings should play reference role in eco-architecture design forming bionics foundation. The new way was created for architecture structure with strong environmental adaptation.

Keywords: Bionics, Eco-architecture, Structure bionics, Structure Design

Solid desiccant dehumidification techniques inspired from natural electroosmosis phenomena

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Abstract

Electroosmosis has been shown to be an effective means of different applications in various fields such as MEMS and biomimetics applications. In this paper, the electroosmotic flow inside the porous medium is validated experimentally to further understand the dehumidification mechanism of combined techniques. An experimental test validated that condensation from porous medium can be obtained by electroosmotic force generated by external electric field. These promising phenomena can be an alternative way to energy choice in dehumidification industrial field. Researches on new regeneration methods for solid desiccant dehumidification are required to be further to make the system simple, energy saving, and suitable for small air conditioning units.

Keywords: Biomimetics, electroosmotic flow, Solid desiccant dehumidification.

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Research Activities in Nature-Inspired Technology at KIMM

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Abstract

Various researches related to nature-inspired technology are in progress. Our research activities in this field are presented.

One major research involves the fabrication of the totally implantable artificial cochlea. The artificial cochlear implementation is the most promising solution for the hearing loss caused by the cochlear damage. However, the conventional artificial cochlea has several disadvantages such as the disclosure of disability, large power consumption requiring frequent recharge, and the inconvenience of carrying external components. In our research, a bio-inspired, totally implantable artificial cochlea that requires minimum power will be designed based on the artificial basilar membrane and the stereocilia. This technology will significantly improve the overall quality of life of patients with hearing loss.

The biomimetic fabrication of the hierarchically structured nature surfaces is another research area in nature–inspired technology. Researches on mimicking lotus leaf and moth eyes are in progress. Lotus leaf has the property of superhydrophobicity resulting from the hierarchical structure and the low-surface-energy chemical layer. This is the reason for the lotus effect, or self-cleaning effect. By using the colloidal lithography, the surface with hierarchical structure that contributes to the superhydrophobicity is fabricated. Moth eyes are also mimicked for the antireflective property. Moth-eye mimetic glass shows wide-range wavelength antireflectivity and small reflectance variances that the optical performance of device can be improved by using the mimetic glasses. Lotus-leaf and moth-eye mimicking surfaces can be used for solar LEDs and contribute to environmental sustainability.

Another research activity related to this field is the fabrication of three-dimensional (3D) scaffold. Scaffolds are used to regenerate an organ with impaired tissues. Using 3D scanning and plotting system, the shape of organ is scanned and scaffolds are fabricated mimicking the structure of original organ. The cell-seeded biomimetic scaffolds can be implanted and repair damaged tissues.

The use of ontology in biomimetics

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Abstract

An ontology is a repository for information and knowledge. It contains information both about a particular subject area (*domain*) and about the interrelationships between the various items of information. Items of data are organised into hierarchies and can have a variety of interactions – positive, negative, exclusive, global, single, multiple, etc. This is much more powerful than a database, and can be developed into an AI tool for reasoning and providing information. In biomimetics, where the differences between biology and engineering need to be mapped in order to generate a pathway between the two, an ontological approach can open the way for solving problems in a biological, and therefore (one hopes) sustainable, fashion. The ontology which will be described is written in the PD program *Protégé* and the Web Ontology Language (OWL). It uses the Russian system TRIZ (itself readily susceptible to expression as an ontology) to provide a classification of technical problems and their solution.

Toughening mechanism analysis of nacre and its inspiration on biomimetics

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Abstract

In this study, a linear elastic fracture mechanics framework is developed for investigating the toughening and strengthening mechanism observed in nacre. A half-infinite crack configuration is employed to obtain the toughening ratio. An equation governing the stress intensity factor is proposed and a general framework for solutions is established. The toughening ratio, the ultimate material strength and the flaw-tolerance of nacre and nacre-like composites are then investigated together with the effects of platelet thickness and length, the composite stiffness and interfacial mechanical properties. The results demonstrate that the presence of platelet bridging in nacre is an important contribution to its high toughness, high strength and superior flaw-tolerance. In addition, it was shown that the aspect of platelets, nacre stiffness and interfacial strength in nacre significantly contribute to those outstanding mechanical properties mentioned above.

These results provide insights into the platelet bridging features that make nacre tough, stiff, strong and flaw-tolerant. Based on these results, some design guidelines for novel materials mimicking nacre have also been proposed. We suggested a novel self-assembly method to produce novel materials with hierarchical structures and enhanced performance.

Keywords: Nacre, Biological material, Biomimetics, Microstructure, Toughening mechanisms, Fracture model.

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Simulation Study on Dynamic Behavior of the Soil / Earthworm Interface

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Abstract

The simulation model of the dynamic behavior interface between the earthworm surface and soil was established by software PFC2D. Comparative analysis of the smooth and corrugated surface contact interface, contact force, particle number as well as the sliding contact resistance, and the results are as follows: when the corrugated surface resultant force of the friction and backward thrust was less than the smooth surface friction, then the corrugated surface was drag-reducing. If the backward thrust is too large, the corrugated surface will be increasing resistance. The corrugated surface disturbed soil more than the smooth surface during move forward. Both smooth surface and corrugated surface, the sliding resistance was increased with increasing the vertical load, but the drag-reduction effect of the corrugated surface was declined. As forward speed increases, the sliding resistance increased; but the trend of increase of corrugated surface becomes slower than the smooth surface, and the drag-reducing effect was good at high-speed. The results showed that: The drag-reducing capability of the non-smooth surface relate with contact interface and external conditions. The above study provides research method and reference for revealing the drag reduction mechanism of the non-smooth.

Keywords: Discrete element method, Earthworm, Contact interface, Slide resistance

Effect of internal viscoelasticity on passive kinematics of a beam in a two-dimension inviscid flow

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Abstract

Fins and wings are the key propellers for fish and insect respectively. To study the mechanism of animal locomotion, the fins and wings are simplified as models of rigid or flexible beams. In this paper we simulated the analogy system of a flexible beam immersed in a uniform stream and studied the effect of the internal viscoelasticity on the system. Results show that the viscous component of the beam decreased the mechanical energy of the beam. With the internal viscosity increasing, the energy dissipation rate of the beam firstly increases and then decreases.

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Efficient Solar Cell Hidden in Butterfly Wing Scales

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Abstract

Solar energy is a kind of clean, high efficient new energy which will never be exhausted. Especially in new century, more and more governments would use solar energy resources instead of oil, coal and other resources which can not be recycled. The low light absorption is the major problem at present. To improve the light absorption, researchers are studying different aspects such as crystal phase and size, doping methods, optimized materials and proper structures. The light absorption increases with increase in the optical path length. Consequently, developing a light trapping model which can increase the optical path length is effective to achieve better light-collection performance.

Recently, studies on butterfly wings show that some microstructures on the wings surface are effective solar collectors. The optical properties of the butterfly wings have a structural origin, the scales are arranged on a butterfly wing in arrays of precise and repeated structures, the complex groove shapes display several optical effects, such as interference, scattering, and diffraction. Based on these mechanisms, butterfly wings can absorb more heat rapidly, and then increase the individuals' body temperature fast, enhance the survival chances of the butterfly in high and cold area.

In this paper, five kinds of Parnassian inhabit in the high-altitude areas were studied. Reflectance spectra in the 200-850nm wavelength range were taken by using UV-VIS spectrometer to select the butterfly of lower reflectivity. The general form and geometry dimension of the scales and arrangements were observed by using the stereomicroscope. By using the scanning electron microscope (SEM), the 2D morphology and structure of the single scale surface were examined. Then, with the help of transmission electron microscope (TEM), the dimension and the structure characteristics of the cross section were obtained. Combining the SEM 2D data and TEM data, the 3D optimized configurations were formed, and several 3D single scale models were described by using the pro-Engineer software. The mechanism was analyzed to reveal the secret that microstructures lead to higher absorption. The spatial features of the scale with higher absorption can be used for the development of samples with desirable functionalities.

Keywords: butterfly wing, scale, microstructure, sunlight absorption

Numerical characterization of surface structures of slippery zone in *Nepenthes alata* pitchers and its mechanism of reducing locust's attachment force

Lixin Wang, Qiang Zhou*
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Abstract

The slippery zone of inner pitchers in carnivorous plant *Nepenthes alata* bears highly specialized structures to serve the functions of trapping insects and restricting escape of preys. Since the surface structures of slippery zone may influence locust's attachment, surface micromorphologies of the slippery zone were observed with scanning electron microscope (SEM) and scanning white-light interferometer (SWLI) to investigate the micromorphologies and geometrical dimensions of the surface structures. Attachment force of locust (*Locusta migratoria manilensis*) was measured on the slippery zone with different slanting angles, as well as measured on stainless steel plate for the purpose of comparison. The influences of slippery zone on locust attachment force were analyzed based on the viewpoints of micromorphologies and geometrical dimensions of surface structures. The slippery zone surface of *Nepenthes alata* pitchers possesses lunate cells and wax crystals with micro-nano dimensions. Measurement results present that the attachment force of locust on slippery zones is apparently smaller than on stainless steel plates with all the corresponding slanting angles. The surface structures with appropriate geometrical dimensions and physical properties result in the significant decrease of attachment force by means of prohibiting locust generating effective mechanical interlock and adhesive attachment. This research probably provides a suitable theoretical foundation for biomimicking microstructures and functions of slippery zone surface for designing slippery plates for trapping disaster locusts and any other agricultural pest.

Keywords: slippery zone, *Nepenthes alata*, locust, attachment force, surface structures.

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Numerical Study on aerodynamic noise of bionic Airfoil using Large-Eddy Simulation

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Abstract

Since noise from wind turbine is a major problem for the populations that inhabit near them, it is necessary to place a great effort in research to reduce the noise. An example of effective noise reduction in nature is the owl. It is known for long, that the wings of owls possess a very unique geometry and special structures, such as leading edge serrations, velvet-like surface, and trailing edge fringes. Those owl-specific characteristics have an influence on the overall flow field and, thus, on the noise emission of the wing. Applying the geometric information about the shape of the owl wing, a NACA4415 bionic airfoil was built with non –smooth leading edge. The main objective is to study on the connections between an airfoil shape characteristics and its aero- acoustic performance. The aero-acoustic model is coupled to a sub-grid-scale turbulence model for Large-Eddy Simulations. The approach employs the unsteady CFD flow simulations in the near field of an airfoil and the FW-H integral method for the far field noise prediction.

Keywords： Large-Eddy Simulation， Computational AeroAcoustics， engineering bionics，airfoil noise

Abrasive Wear of Geometrical Surface Structures of Scapharca subcrenata and Burnt-end Ark against Soil

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Abstract

Scapharca subcrenata(*Arca subcrenala Lischke*) and Burnt-end Ark (*Arca inflata Reeve*) were selected as the research objects. Experiments were performed by wearing the Scapharca subcrenata node rib pattern shell, Scapharca subcrenata rib pattern shell and Burnt-end Ark against the soil in the abrasive tester. Results showed that the wear resistance of the surface structures of the Scapharca subcrenata node rib pattern shell and the Burnt-end Ark shell is better than that of the surface structure of the Scapharca subcrenata rib pattern shell when the relative sliding speed was 2.41m/s. When abrasive size ranged from 0.380 to 0.830mm, the wear loss of these three types of surface structure were increased as the relative sliding velocity increased.

Keywords: Scapharca subcrenata, Burnt-end Ark, geometrical surface structure, soil, abrasive wear

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Session2: Coupling Bionics/Biomimetics

Lightweight Design of Mechanical Structures based on Structural Bionic Methodology

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Abstract

With increasing concern over the excessive energy consumption and environment pollution, structural bionics is a viable new source of lightweight design by mechanical engineers. The structural solutions derived from nature can be successfully transferred into technical construction for maximum structural efficiency from minimal resources. The goal of the study is to develop a standard methodology for bionic mechanical structures with self-load reduction and performance improvement. Similarity theory and fuzzy assessment method are deployed for analogical samples selection and analysis based on structure, loading and function similarities. The type spectrum of lightweight design is established for selection convenience and principles extraction, vital to concept designs. Finite Element Method is used as an effective tool for mechanical performance simulation and comparison. The Rapid Prototyping, Investment Casting and NC Machining are discussed for model fabrication. The static and dynamic test results are promising that the bionic models are lighter but stiffer than original ones. So by mimicking biological structural principles, the structural bionic design offers a new solution for updating traditional design concepts and achieving maximum structural efficiency.

Keywords: Lightweight, Bionic, Type spectrum, Structural efficiency

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Network Study of Plant Leaf Topological Pattern and Mechanical Property and Its Application

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Abstract

In order to explore the compliance structure and adaptability of the vein pattern of plant leaf, five fresh and mature leaf samples, which represent the typical leaf network in nature, are collected, and the finite element models of the samples are established by simulation. The results show that the topological pattern of plant leaf is self-adaptive to the multi-load fields. When considering the change of wind loads, it is found that the main vein consistently remains unchanged, and the lateral vein changes slightly along different wind load direction. Inspired by the similar work environment and structure, the bionic methodology of wind turbine blade is developed in this paper. Firstly, the wind turbine blade structure is optimized by using SIMP method. The results indicate that material distribution of wind turbine blade is similar to the leaf vein, where, the spar cap of the blade is equivalent to the main vein of leaf, and the skins correspond to the lateral vein of leaf. Secondly, considering the similar stress environment, such as random wind loads, rain, snow, and self-weight, the topology structure of wind turbine blade was decided by referring to the natural structure. Finally, the bionic method is used to design the spar cap region of the blade. The results show that the best fatigue life appears in blades with the ply angle in the range between 45° and 65°. It is not only coincident with the side vein angle of most plant leaves, but efficiently improves the blade fatigue performance.

Keywords: Plant leaf, Medial axis, Self-adaptability, Wind turbine blade, Bionic design

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Numerical Characterization of Surface Structures of Slippery Zone in Nepenthes Alata Pitchers and Its Mechanism of Reducing Locust's Attachment Force

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Abstract

The slippery zone of inner pitchers in carnivorous plant *Nepenthes alata* bears highly specialized structures to serve the functions of trapping insects and restricting escape of preys. Since the surface structures of slippery zone may influence locust's attachment, surface micromorphologies of the slippery zone were observed with scanning electron microscope (SEM) and scanning white-light interferometer (SWLI) to investigate the micromorphologies and geometrical dimensions of the surface structures. Attachment force of locust (*Locusta migratoria manilensis*) was measured on the slippery zone with different slanting angles, as well as measured on stainless steel plate for the purpose of comparison. The influences of slippery zone on locust attachment force were analyzed based on the viewpoints of micromorphologies and geometrical dimensions of surface structures. The slippery zone surface of *Nepenthes alata* pitchers possesses lunate cells and wax crystals with micro-nano dimensions. Measurement results present that the attachment force of locust on slippery zones is apparently smaller than on stainless steel plates with all the corresponding slanting angles. The surface structures with appropriate geometrical dimensions and physical properties result in the significant decrease of attachment force by means of prohibiting locust generating effective mechanical interlock and adhesive attachment. This research probably provides a suitable theoretical foundation for biomimicking microstructures and functions of slippery zone surface for designing slippery plates for trapping disaster locusts and any other agricultural pest.

Keywords: Slippery zone, *Nepenthes alata*, Locust, Attachment force, Surface structures

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Prediction of Subsidence in steep seam mining based on probability integral

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Abstract

The deficiency of subsidence prediction in steep seam mining by the theory of equivalent effect is analyzed. More than 1/2 the area of the subsidence basin is caused by mining of downhill horizontal seam because of the great difference between r1 and r2; r2 is too small that the sinking curve is almost vertical. According to the characteristic that mining depth is quite different in steep seam mining , a new prediction model with variable r is put forward based on probability integral model. The model is better than others for steep seam mining and can be adopted widely.

Keyword: probability integral method, steep seam, major influencing radius, unit mining

Potential uses of biomimetics within future sustainable cities

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Abstract

Humankind is facing a myriad of environmental problems, including climate change, biodiversity loss, food and water scarcity and pollution to name a few examples. Many of the design methods used in architecture, engineering, construction, urban planning and materials science during the 20th Century are failing, as new constraints such as a shortage of natural materials - in particular chemical elements, take effect. The problems will increase in scale and impact in the near future, in particular as demand outstrips supply of materials and as climate change takes its toll on urban habitats not designed to withstand its new challenges, such as increased levels of flash flooding, increasingly strong storm systems and extremes of hot and cold weather.

I believe the solution is to apply biomimetic principles to the design of our cities and urban habitats. My research has led me to believe that in order to build cities that are able to cope with the new environmental challenges facing us, we must take a whole systems approach - creating cities that, like nature are resilient through both their ability to adapt to changing environmental factors and through their carefully tailored designs, which are specific to the challenges presented within their immediate environment. Man has tended to apply generic design principles universally, whereas nature always carefully tailors designs and while there are patterns in nature, every plant, fungi, animal and eco system is bespoke to its immediate environment and circumstances.

My vision is for our future cities to operate as a natural eco system would, wherein at every level a city is sensitive to environmental changes, including the changes bought on by the seasons, as well as day-to-day changes in the level of rainfall, sunlight, heat, etc. The city would fuse both natural and man-made indictors to constantly identify these changes - using some of the concepts of Smart Cities already explored, as well as a range of ideas and technologies not yet developed. Having anticipated environmental changes the city would respond immediately, setting in action a course of adaptations to accommodate the new circumstances. The city would also mimic natural eco systems in other ways, such as recycling waste using natural technologies on site and harnessing natural resources, so the city operated as a stand-alone eco system, able to generate it's own energy, water, food and other critical resources. Each city would integrate technologies carefully tailored to its environment, both natural technologies and man-made technologies inspired by nature, both of which would work in harmony. Essentially the future sustainable city would operate as a constantly adapting organism, that changed from season to season, from day to day and from day to night. Symbiotic relationships would exist between all parts of the city

and its immediate surroundings (i.e. nearby towns and villages).

I believe that aside from being more resilient to the seasons and day-to-day changes, the future city will be more resilient to natural disasters, including fires, earthquakes and floods and I believe man can learn how to create natural disaster resilient cities by observing how natural eco systems cope with such events (i.e. trees in fire-prone regions often have cork bark - cork being a natural fire-retardent). I believe, at a time when forest fires are becoming more frequent in many parts of the world, such as Australia, Greece and the West Coast of America, naturally fire-retardent materials and coatings should be used in buildings, as standard. With the exception of extreme natural events, such as asteroid impacts and major volcanic eruptions, nature usually copes many times better with natural disasters than man - indeed many natural systems rely on natural disasters as part of their life-cycle.

I think that the climatic and environmental challenges that will take place over the coming years and decades will be so extreme that the only way to ensure our future cities can withstand these changes is to employ the principles of biomimetics. I would like to present this idea and some of the concepts and technologies I believe could become prominent features of our future cities. I would value the opportunity to create a workshop or interactive seminar that enabled the participation of delegates and an opportunity for them to feed in their immediate thoughts and ideas - creating a brainstorming session at which notes could be taken, so that after the conference we could disclose some of our ideas and thoughts on how biomimetics could enable humankind to meet the future challenges of city planning.

Reducible Property of a Finitely Generated F[G] Module

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Abstract

Let V be an $R[G]$ module, In the article, an element $v \in V$ is a G-invariant element or simply an invariant element if $vx=v$ for all $x \in G$. G-invariant element will be denoted by $Inv_H(V)$, $Hom_R(V, W)$ is the additive abelian group of all homomorphisms from V to W, The same notation will be used in case V, W are left A modules. and other concepts were introduced, Several lemmas were proved to use these concepts, Finally, using in these lemmas and these concepts, it had been proved that let F be a field whose characteristic dose not divide $|G|$. Then every finitely generated $F[G]$ module is completely reducible.

Keywords: Finitely generated F $[G]$ module, B-projective, R-homomorphism, R-homomorphism

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Simulation Study of Bionic Jetting Direction Influence on Drag Reduction Effect

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Abstract

By imitating the jetting flow feature of shark gills, a bionic jetting model is established by arranging round outlets on a flat plate. The drag reduction effect under different jetting directions are explored using numerical simulation method when the main flow field velocity was 20m/s and the reasons of drag reduction are analyzed simultaneously. The results of simulation showed that different jetting directions affect the wall shear stress and static pressure of flow field which result in the changing of viscous resistance and pressure drag, and the bionic jetting has the best drag reduction effect when jetting direction angle is 30 degrees. Under different jetting direction conditions, the main reason for drag reduction is the substantially decreased pressure drag.

Keywords: Bionics, Drag reduction, Jetting flow, Numerical simulation, Viscous resistance, Pressure drag

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Replication of Butterfly Structural Color Using Magnetron Sputtering Method

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Abstract

This study employed a magnetron sputtering technique to fabricate an ITO-FMMA replica of the multi-layered butterfly scales on the surface of a silicon slice. The optical effect of the replicated scales was examined by using spectrometer. The results showed that the optical characteristics of the replicated scales qualitatively agree with those of the actual wing scales. By using a scanning electron microscope (SEM) and transition electronic telescope (TEM), the nature scale was found to have stacks of thin layers. These observations suggest that the iridescent colors are caused by the microstructure which was optimized to 1D Bragg's stacks. Then the bionic photonic crystal microstructure was simulated by software *translight*. Finally, the optical performances of the simulated scales, replica scales agree with those of the natural original ones. As a result, it can be inferred that the magnetron sputtering technique employed in this study represents a viable approach for the mass production of artificial photonic crystal structures for a wide range of further studies, and for bionic color decoration on some special artworks surface and so forth.

Design and Implementation of Cone Dielectric Elastomer Actuator with Double-slider Mechanism

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Abstract

Dielectric elastomer actuators (DEA) have a wide application prospect in the area of robot due to their merits. The aim of this paper is to improve the displacement of cone DEA, make full use of the large-strain advantage of elastomer, as well as to reduce the volume and mass of actuator. After going through the manufacturing process and working principle of cone DEA, it is deduced that negative preload stiffness can enlarge the displacement of actuator significantly. Then a half-diamond is analyzed using double-slider model in order to have a negative stiffness preload mechanism. Two points from force-displacement curves f_{off}, f_{on} of elastomer with voltage on and off are selected as two working equilibrium positions of actuator to calculate parameters of preload mechanism, thereby realizing the negative stiffness mechanism. Displacement experiments show cone DEA has a displacement of 20 mm under voltage 7541V and experimental results agree well with analytical results. Because the initial displacement is very small, so the large-strain advantage of elastomer is used for displacement of actuator. In addition, the force output of actuator when voltage is on and off is acquired, which shows actuator has a maximal force ability of 1.6N.

Keywords: Dielectric elastomer actuator, Negative stiffness, Preload, Displacement, Force

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Hierarchical and Fiber Corkscrew Structures of Callista Shell and Biomimetic Research

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Abstract

Scanning electron microscope (SEM) observation showed that a Callista shell is a kind of bio-ceramic composite with hierarchical and corkscrew structures. Firstly, it was observed that the composite consists of aragonite layers felted with organic collagen. These aragonite layers consist of aragonite sheets. Further, it was found that the aragonite sheets are made up of nanometer aragonite fibers. It was also found that the aragonite fibers compose a kind of corkscrew structure. The maximal pullout force of the fiber corkscrew structure was investigated and compared with that of fiber parallel structure based on their representative models. It showed that the maximal pullout force of the corkscrew structure is markedly larger than that of the parallel structure. The fiber corkscrew structure was also employed as the design example for the structure of the man-made fiber-reinforced composite, therefore a kind of composite with the fiber corkscrew reinforced structure was biomimetically fabricated. The fracture toughness of the biomimetical composite was tested and compared with that of the conventional composite with the fiber-parallel structure. It showed that the fracture toughness of the biomimetical composite is markedly larger than that of the fiber-parallel composite.

Keywords: Callista shell, Corkscrew structure, Maximal pullout force, Biomimetic fabrication, Fracture toughness

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Cleaning Properties of Dry Adhesives

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Abstract

In this paper we present a study into the cleaning properties of synthetic dry adhesives. We have manufactured the adhesive micro-fibres through a low-cost, high yield fabrication method using Sylgard 184 Polydimethylsiloxane (PDMS) as the structural material. We deliberately contaminated the adhesive samples with different sized particles in the micro and macro scale and tested different cleaning methods for their efficacy with respect to each particle size. We investigated different cleaning methods, which included the use of wax moulding, vibration and pressure sensitive adhesives. For adhesion testing we used a custom system with a linear stage and a force sensor indenting a hemispherical probe into the adhesive surface and measuring the pull-off force. To characterize the cleaning efficacy we visually inspected each sample in a microscope and weighed the samples with a microgram-accuracy analytical balance. Results showed that the moulding method induced adhesion recovery in a greater percentage than the other cleaning methods and even helped with the recovery of collapsed posts in some cases. On the other hand pressure sensitive adhesives seem to have the upper-hand with regards to certain particle sizes that can potentially pose problems with the moulding method.

Keywords: Biomimetic, Dry adhesive, PDMS, Self-cleaning, Gecko, Climbing

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Enhanced Compliant Adhesive Design and Fabrication with Dual-Level Hierarchical Structure

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Abstract

Synthetic dry adhesives, inspired by the nano- and micro-scaled hairs found on the feet of geckos, some spiders, and other animals, have been developed for almost a decade. Single level microscale mushroom shaped fibres structured from elastomers are now able to function even better than the natural adhesive on smooth surfaces under normal loading. However, the adhesion of these single level dry adhesives to natural surfaces is worse because the areas in contact are reduced dramatically on rough surfaces. In nature, this problem is solved by hierarchically constructing different scales of fibres, in order to better conform the adhesive structures to the contacting surface. In this paper, we adapt the nature's solution and propose a novel dual-level hierarchical adhesive design using Polydimethylsiloxane (PDMS) to be tested in peel loading at different orientations. A negative macro-scale mold is manufactured by using a laser cutter to define holes in a Poly(methyl methacrylate) (PMMA) plate. After casting macro-scale fibres from PDMS in the PMMA mold, a previously prepared micro-fibre adhesive is bonded to the macro-fibre structured polymer. Once the bonding polymer is cured, the micro-fibre adhesive layer can then be cut to form macro scale mushroom caps. The individual macro fibre of the resulting hierarchical adhesive is able to conform to different directions of loading. The dual-level structure enhances the peel strength on smooth surfaces compared to an individual level dry adhesive, but can also weaken the shear strength of the adhesive for a given area in contact. The larger geometry fibre shapes appear to be very performance sensitive to the exact shape of their tips, and indicate that designing hierarchical structures is not as simple as placing multiple levels of fibres on top of one another, but can require significant design optimization to enhance the contact mechanics and adhesion strength.

Keywords: Biomimetic, Dry adhesive, Hierarchical, Dual-level adhesive, Silicon

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Simultaneous Optimization of Robot Structures and Control Systems Using Evolutionary Algorithm

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Abstract

This work concerns one of the most important issues for mobile robots; simultaneous optimization of robot structures and its control systems to realize effective mobility on outdoor environment. Recently, various wheeled mobile mechanisms with a passive and/or active linkage mechanism for outdoor environment are developed and evaluated; for example, NASA/JPL developed Rocker-Bogie mechanism installed in Sojourner. We developed the wheeled mobile robot which has six active wheels and passive linkage mechanisms, and its maneuverability was experimentally verified in indoor environment. On the other hand, various kinds of obstacles and road conditions exist on outdoor environments; for example, bump, gap, stairs, dirt road, grassy road and paved road. Mobile robot abilities of traveling on such kinds of outdoor environments depend on its mechanical structures and control systems.

To achieve the effective outdoor traveling, we proposed a simultaneous optimization method for mobile robot structures and control systems using evolutionary algorithm in the dynamics simulation. In our proposed method, a gene of genetic algorithm expresses parameters of the mobile robot structures and control systems. In the dynamics simulator, the mobile robot and controller are developed based on these parameters and the behavior of mobile robots is evaluated. Using the evaluated results, new genes are created and evaluated repeatedly. The bench mark environment in dynamics simulator consist three kind of typical obstacles. The evaluation items for genetic algorithm are traveling distance, time consumption, energy consumption, control accuracy, and attitude of robot.

From the simulation results, the mobile robot could get the enough ability for outdoor traveling around 80th generations. After 80th generations, the other parameters are also optimized until 300 generations. Finally, the optimized gene achieved passing through the three kind of typically environments, small energy consumptions, accurately control, and stable robot attitude.

Keywords: Simultaneous optimization, Evolutionary algorithm, Mobile robot, Rough terrain

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A Review of Nature-Inspired Algorithms

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Abstract

The study of bionics bridges the functions, biological structures and organizational principles found in nature with our modern technologies, and numerous mathematical and metaheuristic algorithms have been developed along with the knowledge transferring process from the lifeforms to the human technologies. Output of bionics study includes not only physical products, but also various computation methods that can be applied in different areas. People have been learning from biological systems and structures to design and develop a number of different kinds of optimisation algorithms that have been widely used in both theoretical study and practical applications. In this paper, a number of selected nature-inspired algorithms are systematically reviewed and analyzed. Though the paper is mainly focused on the original principle behind each of the algorithm, their applications are also discussed.

Keywords: Bionics, Optimization algorithms review/comparison, Ant colony optimization, Bees algorithm, Genetic algorithm, Firefly algorithm

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Successful Application of Evolutionary Algorithms in Engineering Design

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Abstract

Evolutionary or bionic strategies have proven to be powerful tools in many optimisation studies. Starting with some parent generations, producing sets of children, selecting the best children to be new parents yields impressive improvements of the objective when used with some experience and sufficient equipment. During some years of research the parameters of evolutionary optimisation have been investigated. Many successful applications showed where and how to use it. Especially in the case of objective functions with some or many local maxima, evolutionary approaches may propose solutions which gradient based optimisation would hardly find.

When used with a large number of optimisation parameters, evolutionary methods seem to be superior to other strategies, as the chances to find good proposals within an acceptable number of trials and within affordable time are much higher.

Nevertheless, evolutionary approaches like all optimisation methods require large numbers of studies of individual solutions. The computer power necessary to apply these strategies should not be underestimated. Even with today low cost and high availability of computers, the time to solve problems may be surprisingly long. So all ways of parallel processing, using single computers with many processors or clusters of many computers may speed up the time to do the optimisation.

The basic terms of the method are outlined, some problems discussed, some examples given and some proposals made, how to use evolutionary methods in engineering optimisation. Finally some warnings are given trying to prevent potential users from non-realistic expectations. Optimisation is a difficult and consuming process. This holds for evolutionary optimisation as well.

Keywords: Optimisation, Evolution, Parameters, Acceleration, Grid computing

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Biological Coupling Anti-Wear Properties of Three Typical Molluscan Shells Scapharca Subcrenata, Rapana Venosa, and Acanthochiton Rubrolineatus

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Abstract

Molluscan shells are fascinating examples of highly ordered hierarchical structure and complex organic-inorganic biocomposite material. In order to further study their biological coupling anti-wear properties, three typical shells *Scapharca subcrenata*, *Rapana venosa* and *Acanthochiton rubrolineatus* were selected as experimental models in the current study. Stereomicroscope and scanning electron microscopic observations showed that all these three shells had specific surface morphologies and complicated section microstructures. X-ray diffraction and micro-Vikers hardness tester were further applied to analyze the phase compositions and micro-hardness of the shells. The measured results revealed that aragonite was the most extensive phase present in the shell, and had a relatively high micro-hardness. In this paper, the shells were described in details in morphology, structure and material with emphasis on their relationship to anti-wear property. A special structure, pore canal tubules were discovered in the shell of *S. subcrenata* and *A, rubrolineatus*, which probably contributed most to the anti-wear property of the shells. Collectively, it could be concluded that the excellent wear resistance characteristics of the shells resided in the integrated function of multiple biological coupling of elements, and this approach would provide inspiration to the design of new bionic wear resistance components.

Keywords: Molluscan shell, Wear resistance, Bionic, Biological coupling, Coupling element

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Biomineralization of Calcium Carbonate for Controlling Crystal Structure and Morphology via the Hard Template

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Abstract

Based on the basic principles of biomineralization, aragonite/vaterite calcium carbonate ($CaCO_3$) material with a specific morphology were synthesized by biomimetic method under ambient conditions. In our experiments, the Au, Si substrate were used as the template. The obtained composite $CaCO_3$ were characterized by using X—ray powder diffraction (XRD) analysis and scanning electron microscopy (SEM) and Fourier transform infrared spectroscopy (FTIR) measurement. The results showed that the hard templates can also influence the polymorphism and morphology of crystals as the soft templates. When the $CaCO_3$ induced by the Si substrate, the aragonite polymorph forms; while induced by the Au substrate, vaterite crystals are obtained. At the same time, the possible mechanism of interaction between substrate and $CaCO_3$ during the $CaCO_3$ formation process was discussed. For Si substrate, as negative template, the electrostatic interaction is main factor responsible for the controlled crystallization of $CaCO_3$ on template. For Au substrate, the lattice matching factor plays great role in the crystallized vaterite crystal.

Keywords: Biomineralization, Calcium Carbonate, Polymorph, hard template

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Coupling Characteristics of Anterior Cruciate Ligament and Gait Analysis on Anterior Instability of Knee

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Abstract

Knee is the largest and most complicated joint in the human body. Since in humans the knee supports nearly the whole weight of the body, it is the most vulnerable joint to acute injury. Normal knee joint movements are accomplished via an intricate balance between passive ligaments and active muscular components to maintain knee stability and prevent injury. The anterior cruciate ligament (ACL) is a critical passive component to normal knee function which acts to resist anterior rotatory motion of the tibia relative to the femur. The objective of this study is to investigate the coupling characteristic of the ACL, also try to research the kinematics and kinetic coupling characteristic which make the quadriceps asymmetry after the ACL injury. This paper mainly presents some lower extremity data of the patients who had the anterior instability on the knee due to the ACL injury based on an infrared reflective marker system using stereophotogrammetry techniques. The compensatory mechanism and the biological coupling characteristic are analyzed in the paper. The results of time-distance parameters indicate that the efficiency of walking is lower to some extent by decreased gait frequency and speed and prolonged gait circle that lead to unsteadiness of knee after injury. The kinematics data results demonstrate that the joint angle of extremity have adaptable changes produced by nervomuscular control system after injury. The kinemics data show that the other joints of affected extremity and joints of unaffected extremity both have adaptable changes, which is compensation profiting knee stability after injury. The results of this paper provide fundamental information for further study of kinematics and segmental coupling.

Keywords: Biological coupling, Kinematic coupling, Compensatory mechanism

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Experimental Research on the Structure of Swordfish's Crescent Caudal Fin

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Abstract

Swordfish is the fastest fish in the world, which can reach a high speed of 120km/h. Depending on the swing of the caudal fin; swordfish can get the power of swimming. The caudal fin of the swordfish shows crescent and wide broadening which exceed the highest part of the body. The unique caudal fin of the swordfish and the way of swing are the main reasons for swimming fast.

By testing and analyzing the structure of caudal fin of swordfish, the parametric description of the geometric structure is built. R1 and R2 are radius of the two circles, and R1＜R2, A is center distance of two circles. The two circles intersect to form the crescent shape. This research choose the R1、R2 and A as parameters, then make a geometric shape description of crescent.

The research optimizes the structure parameter of swordfish's caudal fin by the method of experimental optimization. The experiment result shows that the smaller aspect ratio may have greater propulsion (R2 much bigger than R1, aspect ratio close to 2) when the swing frequency is above the 2Hz and the increasing aspect ratio may enhance the propulsion when the swing frequency is below the 2Hz.

Keywords: Crescent, Caudal fin, Optimization, Swordfish

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Fabrication and Analysis of the Multi-coupling Bionic Wearable Material

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Abstract

The multi-coupling bionic wearable steel matrix material has been fabricated successfully utilizing the TE reaction of Ni-Ti-C system. Scanning electron microscopy (SEM) and X-ray microdiffractometer results reveal that the multi-coupling bionic wearable material can be divided into three distinct regions, i.e., unit region, interface region and steel matrix region. The phases are composed of TiC and Ni in the unit region without any intermediate phase. The phases are composed of a large number of $FeNi_3$ and a few TiC and Fe_2Ti in the interface region. Furthermore, the existence of the interface region, which provides an essential composition gradient at the boundaries, keeps a metallurgical bonding between the unit region and the steel matrix region. The multi-coupling bionic material has a combination of properties including rigid and flexible, soft and hard. When it is abraded and extruded, this kind of multi-coupling bionic material shows the character of rigid strengthening and flexible absorption. The sliding wear test shows that the wear-resistances of the multi-coupling bionic material are all better than that of the steel matrix material.

Keywords: Multi-coupling bionic, Wearable materials, Anti-wear, TE reaction

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Micro-Tensile Testing of the Lightweight Laminated Structures of Beetle Elytra Cuticle

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Abstract

Quantitative measurements of the mechanical properties of insect cuticle are a useful tool in the development of biomimetic materials suitable for industrial products. In this study, a micro-tensile tester was used to investigate the mechanical properties of elytra cuticle of the dung beetle (Copris ochus Motschulsky). Micro tensile testing show that: yield strength(Fs) =17.12±3.55N, Maximum tensile(Fb) =14.74±4.11N, yield strength (σ_S)=1.4±0.15GPa, tensile strength (σ_b)=1.2±0.21GPa, elastic modulus(E) =14.56±4.20GPa, plastic index(δ) =0.241±0.10. Tensile elongation of the specimens was between 12.1-36.3%. Our results demonstrate that the elytra possesses ductile material characteristics. Field emission scanning electron microscopy (FESEM) was used to investigate the detailed structure of the elytra cross section in both the transverse and longitudinal directions. In the transverse direction, the fibers of the deeper layers of the endocuticle are orientated in a constant, rotated angle with neighboring fibers rotated in relation to each other in the same direction. The fibers in the longitudinal direction show that the epicuticle, exocuticle and endocuticle layers clearly create a parallel hierarchical structure. We believe this is a result of the composite effect of the hierarchical structure. Finally, we developed a laminated model based on the parameters provided by tensile testing, FESEM imaging and nanoindentation measurements, and compared the results of the model to our experimental results.

Keywords: Nanoindentation, Micro-tensile testing, Coupled analysis, Laminated structure

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Progress in the Bionic Study on Anti-Wear Principles of Biological Coupling

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Abstract

The theoretical studies of bionic anti-wear functions have great scientific significance, and the development of bionic anti-wear technique has large practical values in the engineering field. Through rigorous natural selection, biological organisms have evolved exceptional functions highly adaptable to their living environments. Biological organisms can achieve a variety of biological functions efficiently by using the synergic actions of two or more different parts of the body, or the coupling effects of multiple factors, and demonstrate optimal adaptations to the living environment. In this review, we interpreted the phenomenon and fundamental principles of anti-wear functions of biological coupling by reviewing the current status in this research field. Furthermore, the bionic implementation of the biological coupling anti-wear functions and their extensive prospects were introduced.

Keywords: Biological coupling, Anti-wear, Progress, Bionics

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Research on Biological Coupling Characteristics of the Shells of Haliotis Discus Hannai Ino

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Abstract

The surface morphologies, structures and materials of *Haliotis discus hannai* Ino shells were qualitatively studied by means of a stereoscopic microscope，a field emission scanning electronic microscopy, energy dispersive spectrometer and X-ray diffractometer, and abrasive particle wear was qualitatively and quantitatively studied by means of a pin-on-disc apparatus. The results showed that the outer layer surface of *Haliotis discus hannai* Ino shells was non-smooth and had some strumae or similar parallel convex wave. The shells of *Haliotis discus hannai* Ino are polycrystalline composites of calcium carbonate, proteins and glycoproteins, and consist of the periostracum, prismatic and nacreous layers with calcite in the outer prismatic layer and aragonite in the inner nacreous layer. Nacreous layer is a natural composite comprising calcium carbonate in the aragonite polymorph with organic macromolecules sandwiched in between, and the coupling of platelet interlocks and organic materials makes nacreous layer strong and tough.

The abrasive particle wear tests showed that the abrasion resistance was different on the different parts of the shells, and the left of the shells possessed the highest abrasion resistance and the abrasion resistance of the shells was lowest on the edge of the right. The nacreous layer possessed higher abrasion resistance than prismatic layer because of the coupling of structure and materials of nacreous layer.

Keywords: *Haliotis discus hannai* Ino shells, Morphology, Structure, Materials, Anti-wear, Biological character, Coupling

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The Study of Owl's Silent Flight and Noise Reduction on Fan Vane with Bionic Structure

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Abstract

From the bionics engineering point of view, using the biological non-smooth surface in the surface design of the fan blade in reducing fan noise and improving air flow and efficiency is the main goal. Several kinds of Sawtooth-shaped distribution were designed and the non-smooth form on the fan model was realized. The acoustic performance of various non-smooth fan blades was analyzed as reflected when the fan was rotating. To obtain the Spectrum map, wind comparison chart, efficiency curve and other important parameters which came from the comparison between smooth and non-smooth models and the noise of the fan were done. Revealing the non-smooth shape practically was good for preventing formation of off-body vortex which was caused by turbulent boundary layer on the vane surface and it will have reference significance for exploring the mechanism of noise reduction on fan vane.

Keywords: Owl, bionic, Noise reduction, Optimization test

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Study on Camshaft Treated by Bionic Laser Melting Process in Aqueous Media Cooling

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Abstract

Biomimetic coupling wear resistance model was created according to biomimetic coupling phenomenon and biomimetic coupling theory. The model utilize the preparation of aqueous media by laser cooling techniques and process biological coupling unit on the gray cast iron surface according to the organism form. The bionic coupled unit is made in accordance with the laws of organism combination and a bionic coupling surface which is similar to the organism form is produced with material surface which can improve the wear resistance of the camshaft. Studies show that the region treated with aqueous media by laser can get small grains with uniform size. The hardness and wear resistance is improved.

Keywords: Bionic coupling, Laser melting, Camshaft

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Microstructure and Hydrophobicity Properties of the Bionic Coupling Alumina Films Prepared by Hard Anodizing

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Abstract

Superhydrophobic surfaces have considerable technological potential for various applications due to their extreme water-repellent properties. A number of studies have been carried out to produce artificial biomimetic roughness-induced hydrophobic surfaces. The control of the surface micro-/nanostructure and the chemical composition is critical for these special properties. In this paper, hard anodizing technique was used to prepare alumina films on a non-smooth surface of aluminum substrate with convex domes. A non-smooth surface with convex domes was prepared on a chemical polished 2A12 aluminum alloy substrate using the method of pressing with a symmetrically distributed concave hole module. The experimental results presented the modified non-smooth alumina films with octadecanethiol which had a maximum water contact angle of about 152°, while the unmodified non-smooth alumina films prepared by hard anodizing had a maximum water contact angle of about 137°. A laser scanning confocal microscopy (LSCM) and a scanning electron microscopy (SEM) were used for the surface corresponding microstructure of the non-smooth alumina films. It was discovered that the alumina films with pores form process. The wettability of alumina films is reinforced by means of controlling the bionic aluminum films surface microstructure and chemical composition.

Keywords: Hydrophobic, Non-smooth alumina films, Hard anodizing, Microstructure

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Resistance Reduction by Bionic Coupling of the Earthworm Lubrication Function

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Abstract

Based on the biological surface structure, biological lubrication and bionic coupling theory, the resistance reduction characteristic of the surface morphology and surface wettability of the earthworm were researched in this paper. The parameters of surface dorsal pore and corrugation were extracted. According to these parameters, the lubrication mechanism of the earthworm surface was analyzed, the distribution and the number of pores, and surface morphology were designed, and the bionic coupling samples were prepared. The positive pressure, lubricant flow rate and advancing velocity were selected as the experiment factors. Based on the adhesion data of bionic coupling samples from the testing system of biological signal for tiny soil adhesion test, the optimal samples from the bionic coupling normal adhesion were selected through the range analysis. Compared to the normal ones, the soil resistance of bionic coupling samples was reduced by 76.8%. This is of great significance and offers brighter prospects for reducing energy loss in terrain mechanics. Therefore, the research on the bionics, resistance and adhesion reducing mechanism of the earthworm is very important.

Keywords: Earthworm, Biological surface structure, Biological lubrication, Bionic coupling, Adhesion and resistance reduction

Research Advance in Function Characteristics of Dragonfly Wings

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Abstract

The research of dragonfly wing function characteristics in recent years was reviewed and summarized. The study shows that the dragonflies (order Odonata) are supremely versatile, maneuverable fliers in nature because of the special constructions of their wings. The wings of dragonfly possess especial functions in aerodynamics, aviation, balance, wettability and anti-fatigue aspects. The first three functions focus on the mechanics of dragonfly wings and the fourth function is about of the hydrophobicity, all of these have been researched by many researchers. However, the anti-fatigue characteristics have not been further researched up to the present. This review summarizes the first four function characteristics of dragonfly wings in detail and prospects the anti-fatigue mechanism, and proposes testing method about fatigue characteristics of dragonfly wings.

Keywords : Dragonfly wing, Morphology, Structure, Materials, Mechanics of flight, Wettability, Anti-fatigue

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Improved Adaptive Leap Particle Swarm Algorithm Dynamic Optimization Method for Electromechanical Coupling System

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Abstract

Dynamic optimization of electromechanical coupling system is a multi-subject problem on mechanics theory. The optimization of such kind of problem is studied. Particle swarm optimization (PSO) is introduced. In order to resolve the insufficiency, a new kind of adaptive lump particle swarm optimization (ALPSO) is presented and the astringency analysis is done. Finally, ALPSO is used to optimize electromechanical coupling reshape machine tool principal axis system. The results of application example proved that practical optimization parameters can be obtained in limited time by the method, and it is an effective way to solve such kind of a problem.

Keywords: Particle swarm algorithm, Electromechanical coupling system, Dynamic optimization

Session3: Biomaterials ＆Bionic/ Biomimetics materials

Bionic Composite Material Simulation of the Optical Spectra of Plant Leaves

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Abstract

Based on the analysis of the spectral reflectance characteristics, the mechanism for formation of plant leaves, the characteristic factors of reflectance spectra of plant leaves (spongy structure, chlorophyll, water) were obtained. Then, by imitating the structures of plant leaves and petals and utilizing the techniques of water retention and chlorophyll photostability improvement, a novel bionic composite material with analogous reflectance spectrum of plant leaves was designed and prepared. The endurance experiment showed that, its spectrum changed little after the sunlight treatment for three months.

Keywords: Composite material, Bionic, Optical spectrum, Plant leaf

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A New Kind of Magnetometer from Cryptochrome Magnetoreception Mechanism

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Abstract

Cryptochrome, a blue-light photoreceptor which has high sequence homology to DNA photolyase, is supposed to be the most conceivable magnetoreceptor in avian's magnetoreception. Its light-response mechanism is proposed to result from photoreduction of a protein-bound flavin chromophore through intramolecular electron transfer. The cryptochrome magnetoreception focusing on the radical pair mechanism, structure of cryptochromes, theoretical and behavioral evidences and the electron transfer models of inner cryptochrome protein were reviewed. Finally, the superiority of avian's magnetosensitivity was analysized and it was dicovered that the avian's genius radical pair mechanism of the animal may be simulated to develop a new chemical magnetic detection mechanism, or even a new kind of magnetometer, which is different from current magnetic detection technology.

Keywords: Cryptochrome, Radical pair mechanism, Signaling pathway, Electron transfer

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Dielectric Properties of Soft-Core Helical Particles and Fabrication Based on Spirulina Platensis as Templates

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Abstract

Aiming at the lightweight filler particles with good dielectric properties in the composites, helical *Spirulina platensis* were chosen as templates to produce microscopic helical soft-core filler particles by an electroless deposition technique. The morphology and appearance of the coated *Spirulina platensis* was analyzed with optical microscopy and scanning electron microscopy respectively and the result showed that the particles were successfully coated with a uniform metal coating and their initial helical shape was perfectly replicated. The dielectric properties of these helical soft-core filler particles embedded in epoxy resin were studied in detail, which showed that as the coating thickness increase, the real and imaginary part of permittivity of the composites both increase in a frequency of 2–18 GHz. These soft-core metallized helical microorganisms are lightweight and have good dielectric properties. The metal content in the composites is only 6.6 vol% when the percolation threshold occurs. Such low metal content which can reach percolation point is attributed to the filler particles' soft-core structure and long helical shape advantage.

Keywords: Microorganism, Bio-replicated forming, Soft-core helical particle, Electroless deposition, Dielectric property

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Facile Method to Prepare Hydrophobic Coating Based on Wax Self-assembly

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Abstract

Waxes were extracted from *Cinnamomum camphora* (Linn.) leaves, *Bauhinia blakeana* Dunn leaves, and lotus (*Nelumbo nucifera*) leaves severally by chloroform, the waxes were able to self-assemble into different micromorphologies on the glass slides after volatilization of chloroform. The results show that the structures of tubular epicuticular waxes of lotus waxes coating investigated by SEM are almost the same as the fresh lotus leaf surface, while the micromorphologies of *Cinnamoum camphora* (Linn.) leaf surface and *Bauhinia blakeana* Dunn leaf surface are completely different from corresponding wax coatings .The contact angle of a water droplet on the lotus waxes coating is 148±5°, close to that of fresh leaf surface, and lotus leaf waxes consist of a mixture of alkanes, alcohols, fatty acids, esters and a spot of ketones based on GC-MS analysis. Based on these results, hydrophobic coating could be prepared by lotus wax self-assembly, and the same hydrophobic coating could form by dissolving and commixing raw materials according to the components and corresponding proportion of lotus leaf waxes in principle.

Keywords: Hydrophobic coating, Wax, Self-assembly, Lotus leaf

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Mechanical and Thermal Properties of Sodium Silicate Treated Moso Bamboo Particles Reinforced PVC Composites

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Abstract

The main objective of this research was to study the potential of sodium silicate modification on moso bamboo particles as reinforcements for thermoplastic. Moso bamboo particles were modified with sodium silicate aqueous solution (of 0.5%, 1%, 2%, 5% and 10% concentrations). Mechanical properties of sodium silicate treated moso bamboo particles reinforced PVC composites (BPPC) were calculated and compared with raw bamboo particles filled samples. Thermal characteristics of BPPC were studied to investigate the feasibility of sodium silicate treatment on moso bamboo particles. The particle morphology and BPPC microstructure were investigated by scanning electron microscopy. Results showed that tensile strength and modulus of elasticity of BPPC increased before the concentration of sodium silicate solution reached 5% and got their maximum values of 15.72MPa and 2956.80MPa respectively at 5% concentration. Modulus of rupture obtained the maximum value of 27.73MPa at 2% concentration. The mechanical curve decreased as the concentration of solution went higher. Differential scanning calorimetric analysis illustrated that sodium silicate solution treated BPPC performed a better compatibility. More uniform dispersion of moso bamboo particles in PVC matrix was obtained after sodium silicate treatment. Hence, the sodium silicate was a feasible and competitive agent of creating moso bamboo particles reinforced PVC composites.

Keywords: Composites, Moso bamboo particles, Polyvinylchloride, Mechanical properties, Thermal property

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Preparation and Properties of Fe_3O_4 Biomimetic Micro-nano Structure Coatings

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Abstract

Nanoparticle filling is one of the most effective methods of building the micro-nano structure. In this paper, the composite coatings containing Fe_3O_4 nanoparticles were prepared from fluorinated silicon polymer by in-situ polymerization. FT-IR was used to characterize the structure of the composite material. The SEM and AFM photos of the coatings show that the micro-nano multiple structures which are similar to the lotus leaf surface is constructed due to the addition of Fe_3O_4 nanoparticles which changes the morphology and surface properties of the coating. The contact angle of the coating surface increases first and then decreases with the content of nanoparticles increasing, which closely related to the nanoparticles dispersion in the coating systems and the micro-nano structure of the coating surface. The results show that the biomimetic micro-nano structure of the coatings formed on the glass plate is exactly similar to that of the surface of lotus leaves.

Keywords: Micro-nano structure, Fe_3O_4 nanoparticles, In-situ polymerization, Biomimetic

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Role of Biopolymer Played in Nacre Heat Treatment

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Abstract

The nacre of abalone shell was analyzed with heat treatment to reveal the role of biopolymer which was considered as one of the most important factor for the amazing mechanical properties of nacre. In the N_2 atmosphere, the abalone nacres were heated at 200℃, 400℃ and 600℃ for 5 hours separately. The mechanical properties and microstructures of these samples were observed and compared to that of the fresh one. XRD，TGA and DTA were also performed on the above samples. The results show that there is a phase transformation from aragonite to calcite and the biopolymer degraded more and more according to the temperature of heat treatment. The microstructures of nacre remain at 200℃, 400℃ and 600℃, but a sharp loss of the mechanical properties of nacre happens at 200℃, and an even sharper loss at 400℃ and 600℃. All the analyses reveal the important role of biopolymer playing in nacre.

Keywords: Nacre, Mechanical properties, Biopolymer, Heat treatment

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Tribological and Electrochemical Study of Biomimetic Synovial Fluids

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Abstract

In this study, tribological and electrochemical performance of the new biomimetic synovial fluids were studied according to different composition concentrations, including hyaluronic acid, albumin and alendronic acid sodium. By using Taguchi method, the composition contents of the biomimetic synovial fluids were designed. Items such as friction coefficient, mean scar diameter and viscosity were investigated via a four-ball tribo-tester, viscosity meter and optical microscope. Polarization studies were carried out to analyze the electrochemical behaviour of the fluids. Results show that hyaluronic acid dominates the viscosity of the fluids. High albumin concentration will reduce friction, while increasing wear rate due to the electrochemical effect. Alendronic acid sodium is found to reduce the biocorrosion of CoCrMo as well as provide better lubrication. In conclusion, biomimetic synovial fluids partially recover the functions of natural synovial fluids and provide good lubricating property.

Keywords: Biomimetic synovial fluids, Artificial joint, Wear, Polarization test

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Wear Behavior of Ultra-high Molecular Weight Polyethylene Filled with zinc Oxide Whisker

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Abstract

The artificial joint material of UHMWPE composite filled with zinc oxide whisker (ZnOw) in different compositions was prepared with the pressing formation method. Hardness, micro-scratch and shear punch behavior of ZnOw/UHMWPE composites were measured with UMT tester. Biotribological behavior of the composites was investigated under multi-directional motion with calf bovine synovial lubrication. The experimental results indicated that filling ZnOw increased the hardness and density of UHMWPE composites. The scratch coefficients of composites initially increase up to fluctuating values within 10 seconds. The amplitudes of fluctuation in scratch coefficients for UHMWPE composites are in sequence of the ZnOw filler content of 20%, 10%, 5% and pure UHMWPE. The shear punch results indicated that UHMWPE composites show similar bilinear load-displacement curves, which are characterized by three stages including the initial stiffness, hardening stiffness, and peak breaking load. Filling ZnOw had little effect on the initial stiffness, but increased the breaking load and work failure. The wear resistance of UHMWPE composites was increased by incorporating ZnOw, and a negative linear function was found between the wear rate and breaking load, work failure.

Keywords: UHMWPE, ZnOw, Punch, Wear

Intercrossed Microstructures of Hydroxyapatite Sheets of Tibia Bone

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Abstract

The observation of scanning electron microscope (SEM) showed that a tibia bone is a kind of bioceramic composite consisting of hydroxyapatite layers and collagen protein matrix. All the hydroxyapatite layers are parallel with the surface of the bone and consist of numerous hydroxyapatite sheets. The observation also showed there is a kind of intercrossed microstructure of the hydroxyapatite sheets. In which the hydroxyapatite sheets in an arbitrary hydroxyapatite layer make a large intercrossed angle with the hydroxyapatite sheets in its adjacent hydroxyapatite layers. The maximum pullout force of the intercrossed microstructure, which is closely related to the fracture toughness of the bone, was investigated and compared with that of the parallel microstructure of the sheets through their representative models. Result indicated that the maximum pullout force of the intercrossed microstructure is markedly larger than that of the parallel microstructure, which was experimentally verified.

Keywords: Tibia bone, Hydroxyapatite sheets, Intercrossed microstructure, Maximum pullout force

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Biocompatibility and Conductometric Property of Sol-Gel Derived ZnO/PVP Nanocomposite Biosensor Film

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Abstract

Nanocrystalline ZnO and ZnO/PVP nanocomposite films have been prepared by the sol-gel dip-coating technique from zinc acetate precursor on silicon wafer and Pyrex glass substrates. The films were characterized using atomic force microscopy for morphology, and X-ray photoelectron spectroscopy and Fourier transform infrared spectroscopy for chemical analysis. Thermally untreated and annealed films were studied in order to analyze the influence of temperature on the formation and properties of the films. The films have a uniform void-free surface and the grain size increases with the annealing temperature. The cell viability assays indicate that the growth rate of BPH cells incubated in the presence of ZnO was significantly reduced (35% of the control) compared to that of untreated controls, indicating antibacterial activity of ZnO as a result of generation of hydrogen peroxide. The sensor characteristic of ZnO/PVP nanocomposite was also demonstrated by measuring the change in conductivity upon exposure to superoxide anion radical.

Keywords: Zinc oxide film, Biosensor, Nanocomposite film, Sol-gel

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Flame Propagation in Combustion Synthesis of Ni - Ti Structural Bioimplant Material

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Abstract

This paper integrates analytical and experimental investigations of thermal and combustion phenomena during the self-propagating combustion synthesis of Ni - Ti intermetallic for structural bio-implant application. Ni - Ti mixture is prepared from elemental powders of Ni and Ti. The mixture is pressed into solid cylindrical samples of 1.1 cm diameter and 2 – 3 cm length, with initial porosity ranging from 30% to 42%. The samples are preheated to various initial temperatures and ignited from the top surface such that the flame propagates axially downwards. The flame speed images are recorded with a motion camera and the temperature profile is recorded.

Keywords: Combustion Synthesis, Intermetallic, Bio-implant material

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The Impact of Tissue Morphology, Cross-Section and Turgor Pressure on the Mechanical Properties of the Leaf Petiole in Plants

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Abstract

The petiole is an organ that connects the leaf blade with the stem of the plant. Structural geometry and material properties govern the way in which the petiole complies with wind and gravitational forces. From a structural viewpoint, the petiole resembles a cantilever beam that should resist torsion due to wind and bending due to gravity acting on the leaf blade. A petiole can be considered as a hierarchical cellular structure that broadly consists of three integrated tissues: epidermis, collenchyma and parenchyma. Its structural stiffness is thus determined by the composition of these tissues, their relative density and their spatial distribution, as well as by the morphology of the whole organ. Besides these, another key factor affecting the mechanical response of the petiole to external loading is the water content which governs the turgor pressure within the organ. The hydrostatic conditions within the petiole vary during ontogeny and across time and space, depending largely on the environmental water levels. This paper describes a study of petiole structural morphology in which tissue materials, cross-sectional geometry, layer-architecture and hydrostatic condition are variables that affect the overall structural properties of the organ. *Philodendron melinonii* is selected as a model species for characterizing the mechanical properties of the petiole. The shape of the petiole is modeled through the polar parameterization of the Lame's curves, i.e. Gielis formulation. A multiscale model of bending stiffness is proposed to capture the impact of changing the constituent tissues and the cross-sectional geometry. Stiffness and density of different tissues are used to plot the domain bounded by the limiting curve of the respective tissue material. Shape parameters and the respective tissue properties are used to generate structural efficiency maps displaying property domains within which all possible combinations of tissues that are shaped into a certain geometry during growth fall. The turgor pressure is also taken into account to show how the domain of the effective material properties changes with water content. Finite Element Analysis besides experimental data is used to validate the theoretical results. The maps may offer a source of inspiration for biomimetic design, as they help to gain insight into the efficiency of biological beams described by different tissue properties, geometry and turgidity.

Keywords: Leaf petiole, Structural hierarchy, Turgor pressure, Shape transformer

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Application of Uniform Design in Optimizing Formulation of Friction Materials and Analysis of Friction and Wear Behavior

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Abstract

In this article, uniform design method was employed to design the experiment for optimizing formulation of friction materials. In addition, the friction and wear of the friction materials based on the optimized formulation was tested on the constant speed friction tester (JF150D-Ⅱ), using pad-on-disc contact mode against gray cast iron discs. The friction mechanism was discussed and the worn surfaces of the friction materials were examined by scanning electron microscopy (JSM5310). The results showed that the uniform design method was a better method for finding the optimum formulation of the friction materials with better braking performance. Compared with the other two kinds of friction materials, the friction materials based on the optimized formulation possessed high and stable friction coefficient and high wear resistance, even at the disc temperature of 350℃. The adhesion, strain fatigue and abrasive wear were the main wear mechanisms of the friction materials and there existed tribo-chemical processes and plastic deformation on the worn surface layer.

Keywords: Uniform design, Friction materials, Formulation, Optimize, Friction, Wear

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Biomimetic Anti-Abrasion Surfaces of a Cone Shaped Component against Soil

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Abstract

The geometry of biomimetic surfaces of soil animals were imitated and modeled on a cone component surface (the measuring tip part of a soil cone penetrometer). These biomimetic surfaces are formed by concave dips, convex domes and two wavy forms. The conventional cone surface and the biomimetic cone surfaces were analyzed in ANSYS 11.0 program to estimate cone equivalent stress and soil equivalent stress. Results showed biomimetic surfaces with the geometrical structures found on animals have lower cone equivalent stresses and soil equivalent stresses as compared with the conventional surface. The least maximum cone equivalent stress (CES) and least maximum soil equivalent stress (SES) were recorded by biomimetic surface with concave dips and wavy form-2 respectively. The abrasive wear of biomimetic cone surfaces and conventional (smooth) cone surface were run on a rotary disk type of abrasive wear testing machine. The biomimetic cone surface was found to have lower abrasive wear as compared with the conventional surface. It was found biomimetic cone surface with concave dips have the lowest abrasion wear among all the surfaces.

Keywords: Cone form component, Abrasive wear, Biomimetic design, ANSYS simulation.

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Effect of Surface Roughness on Wettability for Nano-Crystalline Cu Films and Cuo Films with Hierarchical Structure

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Abstract

Nano-sized Cu films and CuO films having hierarchical structure similar to lotus-leaf were fabricated by an improved electroless plating technology and an isothermal oxidization method, respectively. A water contact angle of 138.0^{o} was obtained for the copper film with surface roughness of about 11.56nm and a water contact angle of 106.0^{o} was attained for cupric oxide films with roughness of about 14.48nm. Results show that the water contact angle decreases with roughness increasing for as-fabricated films. The wettability mechanism of Cu films and CuO films was analyzed based on the result of Field emission scanning electron microscopy (FESEM) and Atomic force microscope (AFM) and Water contact angle (WCA).

Keywords: Nano-sized, Cupper and Cupric oxide, Hierarchical structure, Surface roughness, Water contact angle

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Effect of Thermal Fatigue Loading on Tensile Behavior of H13 Die Steel with Biomimetic Coupling Surface

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Abstract

The effect of thermal fatigue cycle on the tensile properties of H13 die steel specimens with different surface (several types of biomimetic surface and a smooth surface) was compared and investigated. The key feature of this biomimetic surface is to arrange a various types of striations to create a non-smooth working surface. Due to the coupling effects of the morphological features on the surface and the microstructure characteristics within unit zone, the specimens with biomimetic coupling surface exhibit remarkably enhanced ultimate tensile strength (UTS) and 0.2% yield strength (YS) compared with reference specimens (namely specimens with a relatively smooth surface) while corresponding ductility remains largely unaffected, regardless of whether there is thermal fatigue loads or not.

Keywords: Biomimetic surface, Coupling, Thermal fatigue, Tensile property, h13 steel

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Effects of Bamboo Fiber on Friction Performance of Brake Materials

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Abstract

This research was conducted to investigate the effect of bamboo fiber on friction and wear properties of friction composites (FC). The friction composites with bamboo fiber content of 0%wt 3%wt, 6%wt 9%wt, and 12%wt respectively were prepared and slid against cast iron disc, and its friction and wear properties were evaluated by a comprehensive evaluation method. It was found that the friction coefficient (μ) of the friction composites increased with bamboo fiber content. However, at the highest content (12 %wt) there was no significant increase of the friction coefficient found. The volume wear rate (ν) of tested friction composites slightly increases with bamboo fiber content (0%wt, 3%wt, and 6 %wt) and temperature. The friction coefficient and wear rate of friction composites with 6%wt bamboo fiber were found to be 0.4 and 0.8, respectively. The character of friction layer and the morphologies of worn surfaces were analyzed by scanning electron microscopy (SEM) and reduction in wear behavior was found. It was demonstrated that wear structure and the carbonized bamboo fiber can reduce wear rate, give stable friction coefficients and reduce noise in friction tests.

Keywords: Friction composite, Bamboo fiber, Friction coefficient, Wear rate

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Friction, Wear and Mechanical Properties of Copper Micropowders (Cmps) Reinforced UHMWPE Composites

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Abstract

Friction, wear and mechanical properties of copper micropowders(CMPs) reinforced Ultra-high molecular weight polyethylene (UHMWPE) composites were investigated in the paper. Friction and wear properties were carried out by an MM200 rig and mechanical properties were measured using an INSTRON-1121 tester and a CHARPY J-4 impact tester. Friction coefficient, wear rate, worn morphology and wear mechanism of CMPs reinforced UHMWPE composites are discussed. The result shows that with CMPs increase, the friction coefficients of CMPs reinforced UHMWPE composite decrease gradually. Evidently, CMPs filled UHMWPE make wear resistance improve. Wear resistance is best when CMPs reach 1% wt in the composite and it decreases slowly when they are more than 1% wt. There are two kinds of wear mechanism of CMPs reinforced UHMWPE composite: adhesion wear and fatigue wear. Abrasive wear appears during sliding wear. When UHMWPE was reinforced with CMPs, its tensile property and impact resistance declines. When CMPs content in the composite change from 1% to 5% wt, fracture of the composites varies from toughness fracture to brittleness fracture.

Keywords: Copper micropowders (CMPs), Ultra-high molecular weight polyethylene (UHMWPE), Composite Sliding wear

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Preparation and Characterization of Sic Whiskers from Rice Husks in Argon Atmosphere

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Abstract

SiC whiskers were prepared through carbonthermal reduction in two steps. Firstly raw rice husks (RHs) were pyrolysed in a graphite vacuum furnace at 460℃ for 2 hours and coked rice husks were pyrolysed at 1400℃ in argon atmosphere. Scanning electron microscopy (SEM), X-ray diffraction (XRD), transmission electron microscopy (TEM) was employed to characterize the morphology and phase composition of SiC whiskers. The result shows that the diameters of SiC whiskers range in 20-200 nm and their lengths are in the range from hundreds of microns to several millimeters. The whiskers are straight and slightly rough and consist of β-SiC crystals with bamboo-like structure. Vapor-solid (VS) mechanism plays a key role at the early stage of SiC formation and VLS mechanism and vapor phase mechanism of the whiskers are involved during the growth of SiC whiskers.

Keywords: SiC whiskers, Rice husks, Pyrolyse

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Study on Anti-Wear Properties of 20crmnti Surface with Biomimetic Non-Smooth Units

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Abstract

The biomimetic non-smooth units were fabricated on the 20CrMnTi surfaces using the laser process. The anti-wear behaviors of biomimetic specimens were investigated experimentally under lubricant rolling condition. The results show that the surfaces of specimens with biomimetic non-smooth unit exhibit higher anti-wear property than the smooth surfaces. The anti-wear property of the surfaces varies with different unit factors (diameter of concave, transverse and longitudinal distance of units) and levels which were arranged by using orthogonal experiment. The optimization of the factors and levels was obtained using range analysis, which shows that the bionic surfaces of samples exhibit the best anti-wear property when the diameter of unit, transverse and longitudinal distance of unit are 250, 270 and 400μm respectively. The enhanced wear resistance is attributed to intensified particles effect by the refinement of grains and the alteration of microstructure in the biomimetic unit zone, which can reduce mass loss by retarding, confining and blocking the abrasive action produced by the debris and preventing pull-out of the materials by plastically trapping them from the wear surface.

Keywords: Biomimetic unit, Orthogonal experiment, Anti-wear, 20CrMnTi

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The Optimization for Laser Processing Parameters and Their Effect on Penetration Depth and Surface Roughness of Non-Smooth Units on the Biomimetic Surface of 3Cr2W8V Steel

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Abstract

Biomimetic Non-smooth surface is a recent development in surface science of materials. One of the important methods to achieve the surface is to manufacture large numbers of non-smooth units by certain techniques, arranging them regularly into the surface layer of materials to form the biomimetic structure. The penetration depth and the surface roughness of units are two crucial factors that affect the properties of materials with biomimetic surface. In this paper, a YAG pulsed laser with varied parameters (electrical current 200-300 A, pulse duration 5-15 ms, frequency 4-10 Hz and scanning speed 0.24-0.72 mm s^{-1}) was used to fabricate these units on the surface of 3Cr2W8V die steel. The penetration depth and the surface roughness of the units were investigated based on orthogonal experimental design. To maximize the penetration depth and minimize the surface roughness, the range analysis and subsequently overall balance method were adopted to identify the most significant factors and levels. Meanwhile the most preferable set of the laser processing parameters was established. The effect of laser processing parameters on the penetration depth and the surface morphology of units was analyzed. The interrelationship among the processing parameter, the penetration depth and the surface roughness was discussed.

Keywords: Biomimetic surface, Experimental optimization, Laser processing parameters, Penetration depth, surface roughness, 3Cr2W8V die steel

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Tensile Properties and Fracture Behavior of Corn Stubble Material

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Abstract

These mechanical properties, the fracture behavior and microstructure of corn stubble were investigated. Tensile testing was performed to evaluate its mechanical properties by an electronic versatile tester. Its microstructure and fracture behavior was explored by Scanning electron microscope (SEM). It was found that elastic deformation, uniform plastic deformation and fracture procedure happened and was shown in the tension-displacement curve of its fibrous root. And three types failure can be recognized from failure curves. For roots of maize stubble, tensile breaking force and diameter significantly represented a linear regression relationship. Tensile results showed the effect of moisture content of corn stubble root on the tensile breaking force and deformation. Fibrous root of corn stubble formed tubular micro-structure, and can be easily divided into inner and outer layer on macro-scale. By microscanning, outer layer consisted of epidermis and cortex while the inner layer was vascular cylinder which fibrous form was composite material and vascular bundles as reinforcing additives for it. Cellular structure with vascular cylinder and cortex with different sizes was clearly found in SEM images.

Keywords: Tensile properties, Fracture, Microstructure, Fibrous root

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A Study of the Velocity Field during Evaporation of Sessile Water and and WaterEthanol Drops

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Abstract

Many studies have investigated evaporation of sessile drops in an attempt to understand the effect of wetting on the evaporation process. Recently interest has also increased in the deposition of particles from such drops, with evaporative mass flux being deemed to be responsible for ring-like deposits, and counteraction of the mass flux by Marangoni convection explaining more uniform deposition patterns. Understanding of such deposition processes is important in biological applications, such as the Litos test-system endorsed by the Russian Ministry of Health for diagnosis of urolithiasis and the evaporation of colloidal drops for depositing and organizing proteins and DNA. In most cases where deposition from evaporating drops has been studied, velocity information is inferred from the final deposition pattern or from mathematical modeling based on simplified models of the physics of the evaporation process. In this study we have directly measured the flow velocities in the base of sessile drops, using micro-PIV, viewing the drop from below, through the cover slide.

For water drops, a radial pattern of flow was observed with a maximum velocity close to but not at the pinned outer edge. For 'azeotropic' ethanol/water mixtures, the velocity field is more chaotic to begin with, passing through a phase involving three or four recirculation cells and finally having the same radial pattern as for water drops.

Keywords: Evaporation, sessile drop, velocimetry, particle deposition, μPIV

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Fabrication of Biomimetic Hydrophobic Coatings on AZ91D Magnesium Alloy Surface

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Abstract

According to microstructure character of typical plant leaf surface such as lotus, the biomimetic hydrophobic coatings on AZ91D magnesium alloy surface were fabricated by means of wet-chemical combining electroless. The samples were immersed into $AgNO_3$ solution in wet-chemical method firstly. Then, the biomimetic hydrophobic coatings were fabricated by electroless after wet-method pretreatment. The microstructure was observed by SEM. The contact angles were measured by contact angle tester. The results indicated that the biomimetic hydrophobic coatings with uniform crystalline, dense structure could be obtained on AZ91D magnesium alloy surface. The results of contact angle values revealed that the biomimetic nano-composite coatings were hydrophobic according to the high contact angle values. The wet-chemical method treatment on the AZ91D magnesium alloy substrate provided roughness microstructure, as a result, improving adhesion of the coating and the substrate.

Keywords: biomimetic, hydrophobic, coatings, magnesium alloy

The Wear-resistance of 3Cr2W8V Steel with Non-smooth Surface in Various Shapes and Distances Processed by Laser

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Abstract

Various non-smooth surfaces that are similar to the surfaces of animal biont are processed on the 3Cr2W8V die steel by laser to improve the wear-resistance and life-span of die. The wear-resistance of various specimens was measured. The results show that the wear-resistances of specimens with non-smooth surfaces are all better than that of the specimen with smooth surface. The shape and distribution distance of non-smooth units affect the wear-resistance of non-smooth specimens because they affect the area ratio and the hardness of non-smooth units. The non-smooth unit with higher hardness can prop load, prevent abrasive particles from penetrating into the matrix material and block the wear process from progressing. The part with lower hardness can absorb energy and make the ploughing and paring of abrasive particle to the non-smooth surface change to roll. Thus the wear-resistance is improved.

Keyword: 3Cr2W8V, Non-smooth, Biont, Laser processing, wear-resistance

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The Influence of Fibre Orientation on Phosphate-Based Glass Fibre/PLA Composites

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1 Introduction

The potential of biodegradable composites to replace traditional metallic devices has many advantages, the main one being that a second surgical event for removal of device would be obviated. In addition, the degradable device should be conducive to the healing process, in addition to other advantages such as being light weight and showing good biocompatibility [1].

To serve efficiently for bone repair during the healing process, the mechanical properties of the composite materials are key factors. The ideal material would allow for the stress to be transferred gradually to the healing bone in order to prevent bone atrophy during the degradation process [2]. This aim of this study was to investigate the role of reinforced fibre orientation on initial composite strength and modulus.

2 Materials and Methods

2.1 Materials

Polylactic acid (NatureWorks 3251D) was used as the matrix and phosphate based glass (PBG) fibres were employed as the reinforcement phase. PLA sheets were prepared using a hot press followed by cooling in a room temperature press.

Fig. 1 PBG fibre/PLA UD Prepreg

Phosphate based glass of formulation $50P_2O_5$ - 40CaO - $5Na_2O$- $5Fe_2O_3$ (in mol %), referred to as P50Fe5, was prepared from sodium phosphate (NaH_2PO_4), calcium hydrogen phosphate ($CaHPO_4$), iron phosphate dihydrate ($FePO_4.2H_2O$) and phosphorous pentoxide (P_2O_5) (Sigma, U.K.). The salt mixture was dried at 350°C for 30 minutes and then melted at 1100°C for 90minutes, after which the glass was poured directly onto a steel plate to cool to room temperature. Continuous fibres were produced using an in-house melt-draw fibre spinning facility and were traversed onto a metal drum for coating and prepreg manufacture.

2.2 Composite Manufacturing

Aligned PBG fibre sheets were coated with PLA/Chloroform solution (5g/dl concentration) and dried in a fume cupboard for 2hrs. The prepreg was then removed from the metal drum after chloroform volatized completely. The prepregs were cut into 140mm x 128mm

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according to the composite mould dimensions (see Figure 1). Randomly orientated non-woven mats were produced from (10mm) chopped fibres dispersed within a Cellosize (Univar Ltd))/distilled water solution at concentration of 2.75g/l (mixed at 600 rpm for 10 min). The disperse fibre was filtered and extracted using a fine mesh strainer to form a mat, before being trimmed to 140mm x 128mm.

Table 1 Composite Preparation

Sample Code	Fibre orientation	RM layer	UD layer	PLA layer	V_f theoretically
RM	Random(RM)	9	-	8	25%
UD	UD	-	8	9	25%
Mixed	RM+UD+RM	4	4	8	25%

Composites were produced by stacking PLA sheets sandwiched with prepared unidirectional (UD) or random fibre mats (see table 1),which were then hot pressed at 210°C for 15 minutes at 38 bars.

2.3 Mechanical Tests

Three point bend flexural tests were conducted according to ISO EN ISO 14125:1998 on specimens of 40x15x2 mm.

3 Results and Discussion

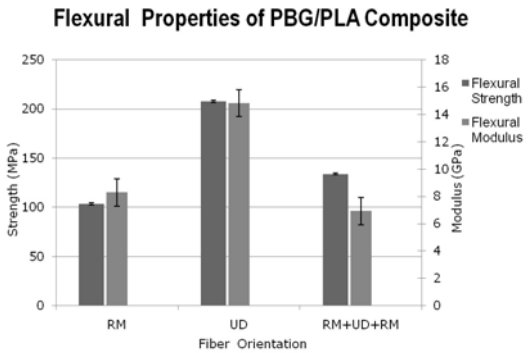

Fig. 2 Flexural Strength and Modulus of the Composites

As seen from Figure 2, the mechanical properties for the UD composites were much higher than the RM and mixed composites (as expected). The strength values obtained for the mixed composite were higher than the RM composite; however, the modulus properties were similar. It is well known that UD orientated fibres have a much greater reinforcing effect due to the stress loads being axially distributed along the fibre lengths. As a result, composites with long fibres oriented in the direction of maximum stress will have superior properties compared to short-fibre composites with random fibre distributions. Future studies will aim to evaluate the influences on retention of mechanical property during the degradation process.

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Superhydrophobic composite films based on THS and nanoparticles

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Abstract

The present paper reports a facile and direct method to render superhydrophobicity onto substrate surfaces. Nanoparticles of various sizes are added into trimethoxyhexadecylsilane (THS) solutions to form superhydrophobic composite films, which exhibit hierarchical structures. The composite films are deposited, in different compositions of nanoparticle concentrations and sizes, on test substrates. For comparison's sake, the composite films of poly (dimethylsiloxane) (PDS) and nanoparticles are also prepared and investigated. The contact angles of water droplets are measured and their change with nanoparticle concentrations and sizes are discussed. Typical structures of those formed surface are observed by using Atomic Force Microscope (AFM) and Scanning Electron Microscope (SEM). Based on the observation and measurement, we investigate how the superhydrophobicity changes with the concentration and size of nanoparticles. Crucial theories involved and related to the phenomena are discussed too.

Keywords: composite film, contact angle, hierarchical structure, superhydrophobic

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Synthesis of High Reflectance Cellulose Films Inspired by the Angiospermous Sponge Mesophyll

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Abstract

Angiosperm is the dominant species of advanced plants on the earth's surface. The design and synthesis of biomimetic materials with special properties by imitating the angiospermous leaves is very attractive in the fields of biomimetics.

According to the extent of sponge mesophyll deferentiation, the angiospermous leaves could be divided into two types, one of which is the bifacial leaves with both palisade mesophylls and sponge ones, and the other is the isobilateral leaves with just sponge mesophylls. It is shown by our tests that the intensity difference of reflectance spectra of those two kinds of leaves between 780nm-1100nm is very obvious. In that spectral range of near infrared, the intensity difference of isobilateral leaves is much more significant than that of bifacial leaves, *i.e.,* some isobilateral leaves show much higher spectral intensity than others. It is evident that the proportion and structures of sponge mesophyll are the critical causes of the high reflectance phenomenon. From the perspective of plant evolution, it could be inferred that the special structures of sponge mesophylls are very important for protecting angiospermous leaves from the harm of excess sunlight. As cell walls of leaves are mainly composed of cellulose, the angiospermous sponge mesophylls show us a potential method to obtain high reflectance films with economic biopolymers, *i.e.*, synthesizing porous cellulose films which imitate the structures of sponge mesophylls.

The synthesis of porous cellulose films was studied by using the environment-friendly N-methylmorpholine-N-oxide (NMMO) solvent method. At first, the hot cellulose/NMMO•H_2O solution was placed on a clean glass circular plate and subjected to spin coating at different rotating speeds for some time in order to produce a viscous cellulose/NMMO/DMSO thin film. Intact films of regenerated cellulose were then produced by immersing the solvated cellulose/NMMO/DMSO-coated glass substrates in the coagulation bath at room temperature for some time to extract NMMO and DMSO. As a consequence, the regenerated material detached spontaneously from the glass substrate to give an intact self-supporting cellulose film that was washed thoroughly with deionized water. The films were dried under vacuum at room temperature for 24 hours and tested with SEM, XRD and UV-Vis Spectrometry.

The influencing factors of the porous structures of cellulose films were analyzed

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accordingly. The studies indicate that the spectral reflectance of the porous cellulose films could be controlled by adjusting the concentration of DMSO and the rotating speed of coating, and be adjusted by changing their water content. Meanwhile, the crystalline properties, *e.g.*, the crystallization index, of the porous cellulose films could be controlled by adjusting compositions of the coagulation bath. The synthesis method of cellulose films with a thickness of 15 to 70 micrometers and a reflectance above 90% was obtained.

The biomimetic porous cellulose films synthesized with the above method is both biodegradable and economic. As the NMMO method used in the synthesis is the same with the well known Loycell method used in cellulose industry fields in principle, the production and application of the high reflectance films is very promising in industrial and domestic fields.

Keywords: angiosperm, sponge mesophyll, high reflectance, cellulose film

Study on the thermal fatigue behavior of the CGI bionic units processed by laser in the water medium

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Abstract

The wear resistance of compacted graphite cast iron (CGI) can be improved by the bionic coupling laser remelting process in the water medium. The wear and the thermal fatigue resistance are the two key factors, which significantly affect the service life of CGI disk brake. Therefore, it is important and necessary to study the thermal fatigue resistance of CGI especially when the wear resistance of CGI can be improved. The bionic coupling units on the CGI surface processed by laser in water medium combining with the substrate form a surface which is similar to morphology of the organism's body. The wear resistance of the bionic CGI gets improved since the microstructure of the unit is much finer than the substrate. However, the crack will easily initiate and propagate in the unit after the lower thermal fatigue test cycles. In this study, the influences of various heat treatment on the thermal fatigue resistance of the bionic unit was investigated making a solid foundation for fabricating bionic CGI components with good mechanical properties. The results indicated that the appearance time of cracks was delayed and the thermal fatigue resistance of the bionic units was improved by the heat-treatment methods.

Study on Mining Subsidence Based on the Key Stratum Theory

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Abstract

The relationship between the starting distance of mining subsidence and the first breaking span of key stratum was studied according to the key stratum theory. The difference, including time and dimension, between experimental result of the starting distance and the first breaking span was analyzed first, and then the theoretical computation method for the starting distance was put forward based on the analysis of their difference.

Keyword: subsidence, starting distance, key stratum, breaking span

Fabrication of Functional Silica-Myoglobin Core-Shell Nanoparticles

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Abstract

Proteins and enzymes display excellent recognizing, binding and catalytic properties that can be exploited to produce functional nanomaterials for biosensing and biocatalytic applications. However, fragile nature of the biomolecules seriously hampers their application potential in biotechnology. As a result, various methods such as sol-gel chemistry, intercalation or molecular wrapping using organoclay oligomers or via microemulsion methods have been used to produce bioinorganic nanocomposites with functionally intact biomolecules. Herein, we show a simple method for the encapsulation of single heme protein using inorganic host matrix. In general, aqueous mixture of tri block-co-polymer such as PEO-PPO-PEO and myoglobin produced polymer-protein nanoconjugates where protein molecules were specifically associated with the hydrophilic-PEO functionality of the block-co-polymer. Subsequently, dispersion of lyophilized powders of protein-polymer composite in cyclohexane produced reverse-micelles contained intact protein molecules. Injection of stichiometric amounts of TMOS precursor to above solution produced discrete core-shell nanoparticles containing met-myoglobin.

Various physico-chemical characterization techniques such as Transmission electron microscopy (TEM), Energy disperse X-ray(EDX), Fourier-transform infrared spectroscopy spectra (FTIR), and UV-vis spectroscopy were used to characterize bio-inorganic nanoconjugates. TEM analysis of samples taken directly from the reverse-micelle solution showed the presence of discrete spheroidal electron-dense nanoparticles with mean diameter of 4.5 nm and was in good agreement with the molecular size of the native myoglobin (4.5 x 2.5 x 3.5 nm), which suggested that individual protein molecule was wrapped with a ultrathin sheath of silica. EDX analysis of bio-inorganic nanoconjugates indicated the presence of elements Fe, S from myoglobin and Si from inorganic matrix. FTIR spectroscopy showed vibration modes at 460 cm^{-1} (Si-O-Si bend), 1108 cm^{-1} (Si-O-Si antisymmetric stretches) for silica as well as amide I (1655cm^{-1} C=O/C-N strech) and amide II (1546cm^{-1} N-H bend/C-H stretches) corresponding to polypeptide chain of protein which clearly suggested that secondary structure of

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encapsulated protein was retained. UV-vis spectrum of native myoglobin showed characteristic spectral signature at 408 nm, where as myoglobin-silica core shell nanoparticles exhibited the soret band at 411 nm, such slightly red-shift of the soret band could be due to constrained environments of the inorganic shell around the protein. However, like native myoglobin, treatment of silica wrapped myoglobin with sodium dithionite resulted in the red shift of the soret band from 411 nm to 430 nm, which was consistent with the formation of encapsulated deoxy myoglobin, which suggested that biochemical activity of silica wrapped protein was retained and protein molecules were accessible for small guest molecules. Our experimental results demonstrate that discrete Mb/silica nanoparticles can be prepared without loss of protein structure and we envisage that such bio-inorganic constructs may have increased potential as a functional nanomaterial for biosensing or biocatalysis.

Keywords: encapsulation, core-shell particle, myoglobin, silica

Terahertz Spectrum of Water in Different Media

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Abstract

THz-TDS is an absorption spectroscopy that deals with the far infrared region of the electromagnetic spectrum. Specific examples of the use of high resolution THz spectroscopy to study and characterize single amino acids, proteins, and explosives point to possibility for unambiguous identification of chemical agents. Since THz spectroscopy probes the molecular absorbance at the lowest frequency regime, this method is uniquely suitable for investigating collective motions inherent in biological activation. For example it has been used to characterize the dynamical transition of cytochrome c, the binding activity of lysozyme with 3NAG, the dynamic comparison between the native and thermally denatured bovine serum albumin. As is well known, water is an extraordinarily important component in the living beings. In bionics, to get further information of the structures and properties of the living beings, water is one of the most important influencing factors, because it provides the environment where the life activity happens and interacts with the biological structures. Furthermore, the metabolism of organism and the transmission of biologic signal are in great need of water. Moreover the life activity and the interaction present varieties in different conditions.

In this work, the interactions between the water and some media at different temperatures are studied. And the analysis of THz region normal modes provides significant insights into the structure-function relationships for biological systems.

High surface energy materials, such as filter membranes, papers, *etc.*, are placed between two polyethylene pellets and then pressed into a sandwich-like pellet after having absorbed enough water. Low surface energy materials, such as silicone resin, *etc.*, are immersed in water for a certain time until they are completely soaked, and then pressed into a new pellet similarly. As for substances with crystal water, such as Pentahydrate Copper Sulfate, *etc.*, the samples with different contents of crystal water are obtained at different temperatures. The protein substances, such as bovine serum albumin, insulin, *etc.*, are hydrated to ensure their biologic activities. As a result, based on the THz spectra of the above samples, the movement states of the molecules are characterized according to the corresponding absorption peak.

As the temperature has a great impact on the interaction between water and the molecule, the THz absorption spectra of the water assume a relatively large difference at

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different temperatures. Under calefactive test conditions, the THz absorption spectra of the substances are investigated. The instrument which has a high signal to noise ratio within the scope of 0.2~2.5THz electromagnetic section is utilized. The changes of the structure movement pattern of the substance are represented in the spectrum. Finally, the theoretical simulation of the spectrum in different conditions is carried out by utilizing the Gaussian 03 software based on density functional theory, and the simulation fits the experiments well.

The THz absorption spectra of water in different media, the absorption coefficient and refractive index obtained from the physical model which collects the THz parameter of materials were acquired. The water interaction with the materials is discussed, and a potential method to investigate the biological material is devised.

Keywords:terahertz, bionics, water

Fabrication of Hierarchical microfiber Arrays Based on Laser Direct Writing Technique

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Abstract

The attachment pads of geckos are covered with long micro to nanosized hairs with characteristic geometries and mechanical properties. This remarkable surface topography enables geckos to firmly attach to and easily detach from almost any kind of surface. As nature reveals, this adhesion concept promises enormous application potential. As a consequence, research efforts have turned to obtaining artificial, bioinspired adhesives. First, simplified analogies consisting of micro-sized vertical pillars with modest aspect ratios were obtained by soft-molding elastomeric precursors on micro fabricated templates, by hot-embossing polymer melts with micro fabricated masters, by lithographically structuring resist films, or by directly drawing polymer fibers. Nanosized pillars with higher aspect ratios have also been fabricated by filling nanoporous membranes with polymer solutions or low-viscosity precursors or as vertically oriented multiwalled carbon nanotubes.

This paper describes one kind of new method for material fabrication of hierarchical bio-mimetic gecko hair arrays, which is based on laser direct writing technique. The dry film RISTON LM8040 is used for array material. This method of fabricating bio-mimetic Gecko hair arrays has advantages of low cost and mass production.

Pillars of different Axial dimensions d (not less than 1μm) and radial dimension (between 1 and 160μm) were fabricated. Based on it, two methods of fabricating hierarchical structure have been invented. One is "Double exposure, Double development"; the other is "Double exposure, Single development". In the preparation process of hierarchical structures, axial dimension is determined by Laser spot size, depth of exposure is determined by exposure time, radial dimension h is determined by development time and finally the pillar density is determined by the density of laser spot array. Laser spot arrays can be easily altered on computer to meet the demand and also the whole control of the preparation process is completed on computer. For instance, a hierarchical structure has been successfully fabricated, the dimension of which is as follows: for Primary structure, axial dimensions d is 2μm, pillar aspect ratio is 2.5, the distance between pillar centers is 4μm; for Secondary structure, axial dimensions d is 50μm, pillar aspect ratio is 3, the distance between pillar centers is 100μm. These methods provide practicability and validity for preparation of multiple structures with soft material.

Keywords: Gecko hair, hierarchical structure, laser direct writing technique, dry film

An electro-mechanical model of ionic polymer metal composites

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Abstract

Ionic polymer-metal composites is a new type electroactive polymer material, which is composed of a perfluorinated polymer membrane coated with a noble metal on both sides. And it has been widely applied to the artificial muscles, soft robotic actuators and dynamic sensors since it has great advantages such as large deformation, low noise, light weight, flexibility and low driving voltage. Typically, the strip of the perfluorinated ionic polymer membrane bends toward the anode (in the case of cation exchange membranes) under the influence of an electric potential. The appearance of water at the surface of the expansion side and the disappearance of water on the contraction side occur near the electrodes. That is to say that cations drag water molecules parasitically with them when they are electrophoretically transported within the IPMC. The electrophoresis-like internal ion-water movement in the nano-channel is responsible for creating effective strains for actuation. In order to effectively describe the deformation law of IPMC, this article established force balance equation of hydrated cation and calculated the concentration of water molecules as well as the water content distribution based on the concentration of hydrated cation distribution and diffusion of water molecules. The relationship between water content and strain was determined by experiments, then the IPMC strain distribution along the thickness could be obtained. The method is suitable for different shapes of actuators. Taking a cantilever IPMC actuator as an example, based on the strain distribution we calculated the output moments and the corresponding output displacement of IPMC sample. The numerical simulation results are similar to the experimental results, which proved that the method is correct and feasible.

Key words: Ionic polymer-metal composites IPMC Actuate model Numerical simulation

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Carcass Compound Materials Base on Fluoropol Ymer for Tissur Engineering in Orthopedics

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Abstract

In this work new type of composite materials for application as coatings for intramedullary implants in the field of orthopaedics and traumatology is offered. Method is based on ability of fluoropolymers to act as biologically inert binding agent and ability of fine-dyspersated hydroxyapatite powders to act as biologically active filling agent providing osteoinduction and osteoconduction processes. Results of investigations of adhesion, elastic and morphometric characteristics of offered composite were presented; chemical composition was determined. Estimation of toxicological properties, locally irritant action and hemolytic activity of offered composites was done according to GOST R ISO 10993. In vivo tests were carried out; it was shown that offered composites didn't cause any negative tissue reactions and stimulated osteogenesis processes in ectopic bone formation test.

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Characterization of self-organized TiO_2 nanotubes on Ti-4Zr-22Nb-2Sn alloys and the application in drug delivery system

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Abstract

Titanium and its alloys have been widely used as base materials for orthopaedic or dental implants due to its excellent biocompatibility, good load-bearing properties and good corrosion resistance. But problems in terms of adhesion and stability for long periods in the living body still exist. Therefore, various efforts are undertaken to further improve the biocompatibility and optimize modifications of titanium surfaces. It is known that small changes in the surface properties can lead to completely different behavior of the material. Therefore, new better modifications of titanium surfaces have been established, for example anodization at lower voltages that leads to highly ordered self-organized TiO_2 nanotubular layer. The Ti base materials show a better bone-binding ability on the TiO_2 covered surface of the implants. However, many clinical investigations show that titanium and its alloys used in corrosive environment like body fluid always release detrimental ions in blood stream of the patient, which could cause severe diseases such as inflammatory, allergic or carcinogenic reactions. Our goal and approach is to keep the advantages of better bone-binding ability for the bulk titanium covered by TiO_2 nanotubes and to eliminate the harmful reactions by carrying drug in the tubes.

In this paper, we investigate the self-organized TiO_2 nanotubes grown by anodization of Ti-4Zr-22Nb-2Sn at different potentials, concentration of NH_4F and anodization time. The morphologies of nanotubes were observed by FE-SEM. The nanotubes with two-size-scale diameters were fabricated at voltages ranging from 10 to 56 V. The tube length and diameters linearly depend on the applied potential. The tube length is also affected by the concentration of NH4F and anodization time. The distribution density of larger diameter nanotubes increases with time. Minocycline hydrochloride (MH), a member of the tetracycline antibiotics, is useful in the treatment of a host of topical bacterial infections. It was selected as the model drug in this current study. The drug-loaded nanotubes were also fabricated in aqueous media containing minocycline hydrochloride. They were characterized by SEM, EDS, XPS and FTIR. The results showed that the drug of minocycline hydrochloride (MH) was loaded in the nanotubes. The release effects were studied in phosphate buffer solution (PBS). The burst release of MH was restrained obviously. The sustaining release time lasted 150h. It is a promising method to eliminate the harmful reactions by carrying drug in the tubes when the titanium alloys were used as biomedical implants.

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Chemically Non-homogeneous Surfaces and Their Influence on Cells Attachment Behaviour

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1. Introduction

It has been shown that high resolution of chemically non-homogeneous surface can be employed to modify the size and shape of attached cells, influencing cell behaviour (*1*). This paper reports a strategy to produce biomimetic chemically non-homogeneous surface by plasma enhanced chemical vapour deposition (PECVD) technology. The results highlight some of the physicochemical factors that may be of importance to biomimetic technique in regulating cellular behaviour.

2. Materials and Methods

Non-treated polystyrene petri dishes were used in this study, biomimetic chemically heterogeneous surfaces were obtained by a masking technique use TEM copper grid as a shadow mask. The PS surfaces were modified with an allylamine plasma using an rf plasma chamber. The chemistry of the resultant surfaces were analysed using a XPS system, the surface wettability was monitored by a water contact angle tester, and surface topography was studied using a SPM in contact mode. The influence of surface physicochemical factors on the cell attachment was evaluated using bone marrow mesenchymal stem cell (HBM MSCs) *in vitro*.

3. Results

Exposure to an allylamine plasma resulted in a 5~10 nm protein-like coating on PS surface. The thin film has a nitrogen and oxygen concentration of 18.79 % and 16.55 atom%, respectively, was detected by XPS analysis. This is primarily due to a hydrocarbon plasma polymer, with oxidized functionalities, being deposited on top of the PS surface. The water contact angle on modified PS petri dish demonstrates a marked increase in hydrophobicity. Chemical AFM examination revealed that a chemically heterogeneous surface, with clear boundary between plasma treated and native PS surface on a masked dish. *in vitro* evaluation using HBM MSCs cells demonstrated that cells attached to the modified region show a flat morphology, indicating strong attachment and spreading; whereas the masked region predominantly shows round cells that are only loosely attached to the surface.

The cell proliferation analysis demonstrated that a low rate proliferation at masked

area (with low surface oxygen & nitrogen concentrations) but rapidly increases at modified areas.

4. Conclusions

Plasma polymerization can be used as a simple, rapid, and cost effective method for surface biomimetic modification of biomaterials for regulating cell attachments and growth. The resulting biomimetic surfaces have both a controllable chemical functionality and a pattern resolution comparable to other more widely used patterning techniques. This work demonstrates that biomimetic patterns with spatial resolution of less than 5 μm can be achieved using patterned plasma polymerisation technique. The patterns can be deposited onto rough surfaces and be used to achieve

spatial control, cellular attachment and proliferation of cells in the field of tissue engineering and regenerative medicine.

Controlled mechanical and swelling properties of PVA/SA blend hydrogels prepared by freezing-thawing followed by Ca^{2+} crosslinking

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Abstract

Polyvinyl alcohol (PVA)/sodium alginate (SA) blend hydrogels with different SA contents were prepared by freezing-thawing followed by Ca^{2+} crosslinking. SEM analysis of freeze-dried samples showed a typical porous structure and high miscibility between PVA and SA media. The effects of SA content, freezing-thawing times and Ca^{2+} concentration on the tension, unconfined compression and pH sensitive properties of the blend hydrogels were investigated. The content of SA exerts a significant effect on hydrogel structure and swelling kinetics. Higher crosslinking density and SA content gave rise to a more notable improvement in compressive modulus. In comparison with pure PVA hydrogel, the blend hydrogels have typical pH-sensitivity which can be enhanced by increasing SA content and decreasing Ca^{2+} concentration.

Keywords: polyvinyl alcohol, sodium alginate, hydrogel, mechanical properties, pH-sensitivity

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Kinematics of Chinese Toad *Bufo gargarizans*

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Abstract

A three-dimensional motion force tester for animal was used to measure the reaction force of *B. gargarizans*`s feet against a solid surface when it crawled on a horizontal plane. The motion behavior of Chinese toad was recorded by a high-speed camera on line. The motor function of every foot was analyzed. It was found that the lateral force represents control ability of side-to-side locomotion and maintain a stable state for the continual creeping attitude. The forefeet play the assistant role, whilst the hindfeet play the main role in driving. The normal force of the forefeet is significantly greater than that of the hindfeet, so the forefeet play the main role in supporting Chinese toad body and the hindfeet play the assistant role. Normal force is significantly greater than the lateral force and the driving force. There is little change for the friction force and the support angle of all the four feet. The average value of the support angle is 70°-80°. Chinese toad vola friction coefficient of the forefeet is less than that of hindfeet. The above results indicate the difference of kinematics and the material characteristic of the contact skin of Chinese toad. The results could be useful in the structure design and gait optimization of some robots.

Keywords: Chinese toad, *Bufo gargarizans*, kinematics, 3-D mo

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Experimental study and model analysis of the performance of Ionic Polymer Metal Composite (IPMC) using casted Nafion membrane

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Abstract

Since Oguro's group presented the property of Ionic polymer metal composite (IPMC) bending behavior under an applied electric field for the first time in 1992, IPMC is considered to be one of the most promising EAP (electroactive polymer), and has experienced rapid growth in academic interest and industrial application. IPMC is an electrically activated polymer (EAP) actuator, which is composed of a perfluorinated polymer membrane coated with a noble metal on both sides. Typically, the strip of the perfluorinated ionic polymer membrane bends toward the anode (in the case of cation exchange membranes) under the influence of an electric potential. The electrophoresis-like internal ion-water movement is responsible for creating effective strains for actuation. And it has been widely applied to the artificial muscles, soft robotic actuators and dynamic sensors since it has great advantages such as large deformation, low noise, light weight, flexibility and low driving voltage. However, IPMC has the major drawback of a low generative blocking force. Therefore, there are increasing demands to enhance the electromechical performance of IPMC in terms of the output force. In this paper, in order to enhance the blocking force, the Nafion membranes with thickness of 0.22mm, 0.32mm, 0.42mm, 0.64mm and 0.8mm were prepared by casting from liquid solution, on the basis of which IPMCs were successfully fabricated by electroless plating. The elastic modulus of the casted Nafion membranes were obtained by a nano-identer, the electric current, the output displacement and the blocking force were measured using apparatus for actuation test of IPMC. Finally, the effects of the thickness on the performance of IPMC were analyzed with a mechanical model of material mechanics. Experimental study and theory analysis indicate that the elastic modulus of casted Nafion membrane and the blocking force increase as the thickness increases; however, the current and the output displacement decrease as the thickness increases. And IPMC with thickness of 0.8mm exhibited the largest blocking force of 6.7gf, the lowest current of 0.14A and the lowest displacement of

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1.27mm at an applied voltage of 3.5V AC and a frequency of 0.1Hz. A selected cantilever model was adopted to analyze the effect of thickness on the blocking force, and the results showed that the actual test complied with the model analysis. Nafion casting is an effective method to improve the blocking force, and actuation behaviors of IPMC are strongly dependent on the thickness. Also, the mechanical model has been proved to be feasible to analyze the performance of IPMC.

Keyword: IPMC, cast, thickness, actuation test, model analysis

Bioinspired synthesis of nanostrucutured titanium oxide using eggshell membranes as a biotemplate

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Abstract

Important properties of advanced materials are strongly related to their architecture, superficial area and crystallite size. The synthesis of complex inorganic forms, which are based on natural structures that can mimic the natural scaffold upon which the cells are seeded, offers a large range of microstructures that can be mimicked. The eggshell membranes are an organic interwoven fibrous material composed mainly of proteins that control biochemical reactions and determine the physical structure of the inorganic fraction. TiO_2 is well known for diverse applications such as photocatalysis and photovoltaics. Titanium dioxide, particularly in the anatase form, is a photocatalyst under ultraviolet (UV) light. Under UV illumination it can carry out hydrolysis; i.e., break water into hydrogen and oxygen. The hydrogen when collected could be used as a fuel. On the other hand, the strong oxidative potential of the positive holes oxidizes water to create hydroxyl radicals. It can also oxidize oxygen or organic materials directly. Titanium dioxide is thus added to paints, cements, windows, tiles, or other products for its sterilizing, deodorizing and anti-fouling properties and is used as a hydrolysis catalyst.In this work, a facile and versatile method is reported to fabricate interwoven hierarchically TiO_2 films. Using the eggshell membrane as the biotemplate and a solution of titanium tetrachloride in an ethyl alcohol medium, a fibrous TiO_2 microstructure could be mimicked.The first step of the process was to remove the internal eggshell membrane from chicken eggs through the acid dissolution of the external shell. The membrane is mainly collagen and it is virtually inert to the acid. After the complete dissolution of the shell, the membrane was rinsed in an acid alcoholic solution to, after this, use in the biomimicking process.The membranes were then immersed in solution of titanium tetrachloride and ethanol for several hours for deposition of the titanium over the surface of the fibers. The functional groups in the eggshell membrane control the nucleation of the inorganic phase and through heat treatment process the crystallite size could be controlled, and the organic phase removed. After heat treatment, titanium dioxide, mainly anatase phase, in the same form as the previous eggshell membrane was obtained. The samples showed porosity varying from nano to micro-scale. The photocatalytic activity of these membranes was evaluated using the photo-oxidative decomposition of methylene blue under UV light.

Session4: Bionic/ Biomimetic walking

A Coupling Analysis of the Biomechanical Functions of Human FootStructure during Locomotion

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Abstract

This study represents a functional analysis of the human foot structure based on in-vivo gait measurements, finite element (FE) modeling and biological coupling theory, with the objective being to achieve a comprehensive understanding of the impact attenuation and energy absorption functions of the human foot structure. In this study, a simplified heel pad FE model comprising reticular fiber structure and fat cells was constructed based on the foot pad MR images. The model was then used to investigate the foot pad behaviors under impact during locomotion. Three-dimensional (3D) gait measurement and a 3D FE foot model comprising 29 bones, 85 ligaments and the plantar soft tissues were used to investigate the foot arch and plantar fascia deformations in mid-stance phase. The heel pad simulation results showed that the pad model with fat cells (coupling model) has much stronger capacity in impact attenuation and energy storage than the model without fat cells (structure model). Furthermore, the FE simulation reproduced the deformations of the foot arch structure and the plantar fascia extension observed in the gait measurements, which reinforce the postulation that the foot arch structure also plays an important role in energy absorption during locomotion. Finally, the coupling mechanism of the human foot functions in impact attenuation and energy absorption was proposed.

Keywords: Biomechancis, Human foot, Locomotion, Finite element model, Bionic engineering, Biological coupling

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A Marsupial Robotic Fish Team: Design, Motion and Cooperation

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Abstract

A bio-inspired marsupial robotic fish system composed of heterogeneous robotic fish is proposed in this paper. A miniature robotic fish, as the "daughter robotic fish", can adapt to some narrow space, while a "mother robotic fish", with a cabin to transport the daughter, possesses the powerful movement ability to improve the mobility and endurance of the team. The structures for mimicking bio-motion and the method for adopting a fishlike-motion are presented. A typical task of "Daughter-Mother following" is given to show how the robotic system works. The motion model is built based on the multi-jointed-plate structure, and an NN controller is trained for the yaw control. The daughter robotic fish adopts a dynamic light source tracking method to follow the mother, and a heterogeneous communication-based finite state machine is presented for task modelling. Experiments are carried out to verify the system.

Keywords: Marsupial robotic fish, Daughter-Mother following, Heterogeneous Communication-based

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A Novel Miniature Virus-Inspired Swimming Robot for Biomedical Applications

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Abstract

This paper proposes a novel concept of virus-like swimming robot in the range of nano to micro scales for biomedical applications. Viruses are submicroscopic, intracellular parasites that consist of nucleic acid genome and protein capsid. Their shapes help them to move within the infected host organisms and attach to host cells. In this paper, main geometrical features of the viral structure are utilized for conceptual design of the virus-inspired swimming robot and resultant thorny spherical shaped body is equipped with a new inclined and concentric multi-flagella propulsion system for operation in low Reynolds number fluid flow environment. In off-propulsion situation a theoretical formula is derived for thrust value estimation. On the other hand, to investigate the robot behavior in the fluid media in on-propulsion condition, flow field around the robot is simulated using a numerical strategy consists of surface methods of regularized Stokeslet and Rotlet theory. For propulsion control of the robot a multilayer artificial neural network is designed and employed then flow field of the robot wake is analyzed using Lagrangian Coherent Structure (LCS) concept. Furthermore, potential characteristics and specific features of this kind of miniature robots are discussed as well as its application. The results indicate the capability of the miniature robot to perform complex missions in low Reynolds fluid flow environment especially bodily fluid systems including lymphatic, urinary and cerebrospinal fluid (CSF) system.

Keywords: Biomimetic Robotics, Virus-Inspired Swimming Miniature Robot, Inclined Multi-Flagella Propulsion, LCS, ANN, Biofluid Flow Simulati

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An improved model design for 3D human segmental kinematic coupling analysis by optoelectronic stereophotogrammetry

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Abstract

The study of three-dimensional human kinematics remains a challenge in the clinics. As a non-invasive technique, the optoelectronic stereophotogrammetry promises a bright future for clinical applications of the in-vivo locomotor evaluation. However, there are still some disadvantages in using this technique like high testing difficulties, poor testing accuracy and high analysis complexity. The objective of this study is to explore an improved modeling technique for the quantitative measurement and analysis of human locomotion. Firstly, a 3D whole body model of 17 rigid segments was developed to describe systematically human locomotion. Then, a novel infrared reflective maker cluster system of 17 body segments was constructed to calibrate and record accurately the 3D segmental position and orientation of each functional body region simultaneously. In addition, the novel calibration procedures and the conception of kinematic coupling of human locomotion were proposed to investigate and analyze quantitatively the segmental functional characteristics of human motion. Eight healthy male subjects were evaluated by the walking and running experiments using Qualisys system [8 cameras, 150Hz] The experimental results we present in this paper demonstrate that: (i) The kinematic coupling of the upper limbs and the lower limbs both appeared the significant characteristics of joint motion, while the torso motion of human possessed remarkable features of segmental motion; (ii). The results also indicated that flexion/extension was the main motion feature in sagittal plane, while the lateral bending in coronal plane and the axial rotation in transverse plane were subsidiary motions during an entire walking cycle regarding to all the segments of the human body. (iii). Compared to traditional methods, these improved techniques have a competitive advantage in the convenient measurement and accurate analysis of the segmental dynamic functional characteristics during human locomotion. Thus, the improved techniques not only can be applied potentially in the rehabilitation engineering of the clinic in the future, but also in the ergonomics and biomimetic engineering.

Keywords: Human Movement Analysis, In-vivo Skeletal System Kinematics, Calibration Technique, Kinematic Coupling

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Artificial Cambered-Wing for a Beetle-Mimicking Flapper

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Abstract

Some enhancements of an artificial hind wing with passive wing rotation that mimics wing vein configuration Allomyrina Dichotoma are presented in this work. Initial camber is introduced into the wing to passively create wing camber during flapping motion and to improve the aerodynamic force generated by the wing during up- and down-stroke. The flexible hinge was moved to the inner area of the artificial wing and maintained between two main veins near wing root area. Stiffness measurement for the previous wing and the wing with initial camber is conducted to compare the stiffness of the two artificial wings and then the similarities of both artificial wings are discussed. Flapping test was carried out by using a previously built motor-driven flapper that can flap at more than 25 Hz flapping frequency to verify the wing camber effect. Finally, performance comparison between uncambered- and cambered artificial hind wings was also undertaken based on the observations by using high-speed camera and wired-flight test force measurement.

Keywords: Flapping wing, Wing camber, Passive deformation, Beetle.

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Bio-mimetic Walking with Distributed Controlled Wave Gait

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Abstract

This paper describes a multi-agent mobile system that walks. In particular, the gate of the system can be considered as an expansion of the ordinary wave gate, since the class of system configuration is not restricted in a line shape. The system consists of a number of identical units with distributed controllers. The homogeneous units are mechanically connected to construct a mobile platform. Every unit has its local controller that communicates only with its adjacent units. This basic configuration of supervisor-less structure affirmatively confines the dependence of each unit to a local area, and therefore any unit can be removed from / add into any part of a system regardless of the timing without disturbing the performance of the whole system. This flexibility of configuration significantly contributes to easy maintenance of units, such as battery charging or hot-replacing for faulty units. Utilizing the flexibility as well, the system is capable to adapt to a variety of tasks including transportation application and to target objects which have various kinds of shape and/or a wide range of mass.

A proposed example unit contains a Gough-Stewart Platform, a symmetrical type of parallel link manipulator, as its leg. The whole mobile system is aimed at transportation platform with high system flexibility, i.e., the system is able to adapt to wide range of target objects. The "digital actuation (D-actuation)" concept is applied to the local unit controller. D-actuation is a concept to drive a mechatronic system with numbers of "digital actuator (D-actuator)" that has only discrete stable states, such as pneumatic cylinders or solenoids. D-actuation yields great benefits: high repeatability, system simplicity, and low cost. Because of the simplicity of the communication data, the control strategy and the concept of D-actuation, the controlling framework can be implemented as distributed and localized one on every unit. The Schlafli symbol is applied to denote the system configurations. For example, 2-dimensional honeycomb like connection of the units is denoted as {3,6}. A simple, but effective, coordinate system, HC/P, is introduced to denote the connection relations among the units in the {3,6} system. In short, HC/P utilizes three axes to describe 2D system, and the redundant triplet notation enables direct and clear computation regarding unit coordinates.

The basic architecture of the unit mechanism and gait controller are justified with simulation results. The performed simulation shows the feasibility of the whole mobile system.

Keywords: Wave gait, Distributed control, Multi-agent system, Digital actuation

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Bionic Control of Robotic Fish: A Case Study

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Abstract

Bionic learning control is proposed and developed for biologically inspired underwater robots, namely robotic fish. This study focuses on learning natural fish's adaptability to complex and dynamic environment to some extent, rather than mimicking streamlined shapes or specific actuators to develop more mechanical prototypes. After explanations on its inherence and principles in the viewpoint of bionics, a case study on robotic undulating fins is suggested and explored to exhibit this proposed control, from biological inspirations to practical control algorithms. In detail, an iterative learning scheme based control is studied combined with a filter to reduce the measurement noise and a curve fitting component, to keep the necessary phase difference between neighboring fin raysis proposed. Moreover, the iterative learning based control algorithm is designed and implemented for practical applications. The experimental results validate that the proposed learning motion control can effectively improve the propulsion of RoboGnilos. For instance, the steady propulsion velocity may be enhanced by over 40% with some specified parameters.

Keywords: Bionic learning control, Robotic fish, Bionic undulating fins, Iterative learning, RoboGnilos, Flow adaptability.

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Computational and Experimental Study on Dynamic Behavior ofUnderwater Robots Propelled by Bionic Undulating Fins

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Abstract

Bionic undulating fins, inspired by undulations of the Median and/or Paired Fin (MPF) fish, have a bright prospective for the new underwater vehicle with higher maneuverability, lower noise, and higher efficiency. In the present study, the computational and experimental methods are introduced. The hydrodynamics characteristics of underwater robots propelled by two bionic undulating fins were computationally analyzed and experimentally validated. Several typical movement patterns were designed for the bionic underwater robots propelled by two undulating fins, such as moving forward, in-situ yawing and yawing as soon as moving forward. These movement patterns were simulated via numerical simulation based on the coupled Computational Fluid Dynamics (CFD) model, and then the characteristics analysis of bionic underwater robots hydrodynamics behavior were validated to be creditable by comparing with the corresponding physical experiments.

Keywords: Bionic underwater robot, CFD, Dynamic behavior, Undulating fins

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CPGs control Method using a new oscillator in robotic Fish

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Abstract

A new oscillator is presented in this paper based on our pervious oscillator (Zhang's oscillator). Using this new oscillator, a bionic neural control system- central pattern generators (CPGs) control system is built. This control system has a two level form. To validate the function of this new oscillator and the control system, simulations and experiments are both carried out, a simple robotic fish is built with three joints, and results show that the the new oscillator, which has a different self feedback nonlinear function from Zhang's oscillator, can be used to control the robotic fish's movement. By adjusting some parameters of the oscillator, the output will change its period or amplitude. Use these characteristics of the oscillator, the robotic fish can realize turning and swimming movement.

Keywords：CPGs control, Oscillator, Robotic fish

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Experimental Investigation on Soil-digging Performance of the Claws of Mole Rat (Scaptochirus moschatus)

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Abstract

Mole rat, a soil-burrowing animal, has high working efficiency during soil digging. Its claws are good biomimetic prototypes. The geometrical characters of its claws provide useful information for the biomimetic soil-cutting technology such as design of soil-cutting tools and soil-excavating tools. The geometrical characters of the toes of the claws of mole rats (scaptochirus moschatus) were analyzed by stereoscopy. It was found that the three toes (toe-1, toe-2 and toe-3) of a fore claw in middle play major role during digging, and they have larger values in length, width and thickness than the two outer claws. So the three toes were selected as test specimens. The solid models (modeled toe-1, modeled toe-2 and modeled toe-3, corresponding to the three toes) of toes of mole rat were prepared by using reverse engineering and rapid prototype technology. The scales of the toe-1 of mole rat and its angle between the back side and the palm side were taken as the main geometrical structure parameters of the model sample (model-4). The effects of the geometrical structure on excavating performance were examined, and the geometric structure, operating depth and forward speed of the model samples were taken as the experimental factors. Then the combined tests of the arrangement mode of the three modeled toes and forward speed were conducted in order to examine the effects of the arrangement pattern on the soil-cutting resistance. The results showed that the soil-cutting resistance of the modeled toe-1 was reduced by 12.80% compared to the model-4. The soil-cutting resistance when employing the three components with arc arrangement of the teeth was lower than that with straight line of the arrangement of the teeth.

Keywords: Mole rat (scaptochirus moschatus), Claw, Toe, Biomimetics, Soil-digging performance

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Fast-speed Precise C-start of a Robotic Fish: Design and Implementation

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Abstract

This paper presents a novel closed-loop method for a multilink robotic fish to mimic the C-start maneuver, in which the turning speed and precision are emphasized. The turning speed is maximized by carefully designed preparatory stage, and the turning precision is achieved by the feedback of the turning angle from a gyroscope and a new design of the propulsive stage. Different types of C-starts are studied based on the different sizes of caudal fins, in order to achieve the highest turning angular velocity. All the proposed types of C-starts are experimented and compared using a 4-joint robotic fish. The experimental results show the fastest angular velocity up to 200°/s and the distinctions between all these different types.

Keywords: Bio-inspired robotics, robotic fish, turning control, C-start, Closed-loop maneuvering control.

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Kinematics of terrestrial locomotion in mole cricket Gryllotalpa orientalis

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Abstract

Mole cricket (Gryllotalpa orientalis) is typical insect living underground. It has three pairs of legs, in common with other insects. However, the front legs of mole cricket are very unusual. Due to the long-term evolution and development, front legs of mole cricket have specialized into a tool used not only for digging or excavating but for walking or creeping. So the terrestrial gait of mole cricket is different from other hexapod insects. In this study, the gait of mole cricket walking on the ground was recorded by using a high speed video camera system. The special gait pattern of mole cricket was investigated by analyzing the kinematics parameters, including stride length, joint angle and body rotation angle. Although the front leg of mole cricket had less duty factor in alternating tripod gait than other hexapod insects, the whole mechanism can steadily accomplish the locomotion of walk on the ground under the compensation of middle leg and trunk. The results show that mole cricket can realize stabilized movement by the coupling of every legs and body which use different modes of movements.

Keywords: Experimental biology, Mole cricket, Kinematics, Terrestrial locomotion, Biological coupling

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Numerical Simulation And Aerodynamic Performance Comparison between Seagull Aerofoil and NACA 4412 Aerofoil under Low-Reynolds

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Abstract

For the aerofoil of small wind turbine working under the conditions of low-Reynolds, the aerodynamic performance of seagull aerofoil and NACA 4412 is contrastively analyzed by the Fluent while the Reynolds-Number is 1×10^5 , 3×10^5 and 6×10^5 . The numerical simulation comparison shows that, when the attack-angle range is 0°~20°, the life-coefficient of seagull aerofoil increased by 24.97%、46.02% and 48.54% compared to NACA 4412 respectively ; when the attack angle is 4°, the lift-drag ratio of seagull aerofoil increased by 40.44%、43.14% and 39.40% compared to NACA 4412 respectively. Under the condition of Reynolds-Number is 6×10^5 , the normal working range of attack angle of seagull aerofoil increased by 16.7% compared to NACA 4412 .Under the same simulation condition, the separation point of NACA4412 aerofoil is closer to the leading-edge than seagull aerofoil . The analysis shows that the unique distribution of the thickness and the camber of the seagull aerofoil is the main reason of the better aerodynamic characteristics under the Low-Reynolds.

Keywords: Low-Reynolds, wind turbine, aerofoil, numerical simulation, aerodynamic characteristics

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Resonance Analysis for Compliant Bionic Jellyfishes

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Abstract

This paper aims to propose an approach for the resonance analysis of bionic jellyfishes in order to investigate their energy efficiency. First, a suitable mechanism is chosen from the previous study. Then, its solid model is drawn, and the approaches of modal analysis by using ANSYS software are presented. Finally, motion simulations with resonance input are conducted by using ADAMS software, and their energy ratios are found. The simulation results show that the required input energy for a bionic jellyfish will be significantly reduced if it swims at the resonance frequency.

Keywords: Bionic, Jellyfish, Compliant mechanism, Resonance analysis

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Propulsion Modeling and Analysis of a Biomimetic Swimmer

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Abstract

We have studied a biomimetic swimmer based on the motion of bacteria such as Escherichia coli (E. coli) theoretically and experimentally. The swimmer has an ellipsoidal cell body propelled by a helical filament. The performance of this swimmer was estimated by modeling the dynamics of a swimmer in viscous fluid. We applied the resistive force theory (RFT) on this model to calculate the linear swimming speed and the efficiency of the model. A parametric study on linear velocity and efficiency to optimize the design of this swimmer was demonstrated. In order to validate the theoretical results, a biomimetic swimmer was fabricated and an experiment setup was prepared to measure the swimming speed and thrust force in silicone oil. The experimental results agree well with the theoretical values predicted by RFT. In addition, we also studied the flow patterns surrounding the filament with a finite element simulation with different Reynolds number (Re) to understand the mechanism of propulsion. The simulation results provide information on the nature of flow patterns generated by swimming filament. Furthermore, the thrust forces from the simulation were compared with the thrust forces from theory. The simulation results was quite agreement with the theoretical results.

Keywords: Biomimetic microrobots, Swimming microrobots, Propulsion of flagella, Flow visualization, Medical application

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Research on the Kinematic Properties of a Sperm-like Swimming Micro Robot

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Abstract

Nowadays, it has been one of the hottest topics for scientists to research the interventional micro robots operating in human lumen. In this paper, a novel sperm-like interventional swimming robot with single tail is presented firstly. The kinematic models of sperm's helical swimming methods are made, so that the motion principles are analyzed numerically. Positions and orientations are displayed graphically as the single-tail micro robot swims in liquid. Also, the displacements and the swimming velocities of the robot in direction x,y,z are plotted. It is shown that, when the single flexible tail screws in liquid environment, the axial and radial propulsion force will generate together thus causing the axial and radial movements. In order to make the swimming micro robot more controllable, an improved sperm-like swimming intervention micro robot with four flexible tails is fabricated and characterized in pipes full of silicone oil. Experimental results show that the sperm-like micro robot can swim efficiently. With the different combinations of the tails' rotation direction, the robot will gain the excellent control performance.

Keywords: Helical swimming, Sperm-like, Interventional therapy, Kinematic properties

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Self-localization of an omni-directional mobile robot based on optical flow sensor

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Abstract

The omni-directional mobile robot has an advantage that the three degrees of freedom motion in 2D plane can be set independently and can move in arbitrary direction whilst keeping same heading direction. For self-localization using onboard sensors on omni-directional robots, dead reckoning is often used by means of measuring the wheel's velocities (motor encoder data) as well as car-like robots. However, omni-directional mobile robots can easily slip by nature of omni-wheels with many free rollers, dead reckoning will not work even if one wheel does not touch the ground. A method to measure odometry data which is not affected by wheel's slip should be introduced to acquire enough quality of self location for omni-directional mobile robots. We describe a method to obtain robot ego-motion using camera images and optical flow calculation, that is, the camera is used as a velocity sensor. In this paper, a silicon retina vision camera developed by Yagi et al. is introduced as a mobile robot sensor, which has good dynamic range against various lighting condition. And a Field Programmable Gate Array (FPGA) optical flow circuit for the silicon retina is developed to measure ego-motion of mobile robot. The developed optical flow calculation system is introduced into a small omni-directional mobile robot and evaluation experiments using the mobile robot ego-motion are carried out. In the experiments, the accuracy of self-location by the dead reckoning and optical flow are evaluated by comparing with motion capture. The results show that a correct position is better obtained from optical flow sensor than dead reckoning.

Keywords: Silicon retina camera, Optical flow, FPGA

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Supervised Neural Q-learning based motion Control for Bionic Underwater Robots

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Abstract

Bionic underwater robots have been a hot research area in recent years. The motion control methods for a kind of bionic underwater robot with two undulating fins are discussed in this paper. The equations of motion for the bionic underwater robot are described. To apply the reinforcement learning to the actual robot control, a Supervised Neural Q_learning algorithm (SNQL) is put forward. This algorithm is based on conventional Q_learning algorithm, but has three remarkable distinctions: 1) uses a feedforward neural network to approximate the Q_function table; 2) adopts a learning sample database to speed up learning and improve the stability of learning system; 3) introduces a supervised control in the earlier stage of learning for safety and to speed up learning again. Experiments for straightforward swimming are carried out with SNQL algorithm. Results indicate that the SNQL algorithm is more effective than pure neural Q_learning or supervised control. It is a feasible approach to figure out the motion control for bionic underwater robots.

Keywords: Bionic underwater robot, Reinforcement learning, Q_learning, Neural network, Supervised control, Database, Undulating fin

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The Biomimetic Construction of Category Mental Imagery Based on Recognition Mechanism of Visual Cortex of Human Brain

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Abstract

It is well known that human brain is the most effective biological intelligent system, which has the functions of perception, recognition, learning, association, memory, reasoning, etc. It is a meaningful and challenging work to investigate these functions and realize them by machine for scientists in information science and bionics. Mental imagery is a basic issue in Imagery Thinking, which plays the important role as a bridge in cognition and thinking. In this paper, the principle of the continuity in the feature space of any one of the certain kinds of samples in Multi-Dimensional Space Biomimetic Informatics is applied to the identifying mechanism of the category of deep representation of mental imagery. The model of each cerebral region involved in recognizing is established respectively, and a feed forward method for establishing category mental imagery is proposed. First, the model for acquisition of feature is developed based on Hubel-Wiesel model, and the simple cell receptive field is simulated using Gaussian function to satisfy the specific function of visual cortex. Second, multiple input aggregation operation is employed to simulate the feature output of complex cells so as to realize invariance representation. Then, imagery basis is extracted using unsupervised learning algorithm based on the primary feature, and category mental imagery is obtained by building Radial Basis Function (RBF) network. Finally, system model is tested by training set and test set composed of real images. Experimental results show the proposed method can establish the valid deep representation of these samples, on which the biomimetic construction of category mental imagery can be achieved. This method provides a new idea for solving imagery problem and studying imagery thinking.

Keywords: Multi-dimensional space biomimetic informatics, Artificial intelligence, Cognitive science, Mental imagery, Visual cortex, Object recognition

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The Human Ankle-Foot Complex as a Multi-Configurable Mechanism during the Stance Phase of Walking

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Abstract

The objective of this study is to investigate the biomechanical functions of the human ankle-foot complex during the stance phase of walking. The three-dimensional (3D) gait measurement was conducted by using a 3D infrared multi-camera system and a force plate array to record the ground reaction forces (GRF) and segmental motions simultaneously. The ankle-foot complex was modelled as a four-segment system, connected by three joints: talocrural joint, sub-talar joint and metatarsophalangeal joint. The subject-specific joint orientations and locations were determined using a functional joint method based on the particle swarm optimisation algorithm. The GRF moment arms and joint moments acting around the talocrural and sub-talar joints were calculated over the entire stance phase. The estimated talocrural and sub-talar joint locations show noticeable obliquity. The kinematic and kinetic results strongly suggest that the human ankle-foot complex works as a mechanical mechanism with two different configurations in stance phase of walking. These lead to a significant decrease in the GRF moment arms thereby increasing the effective mechanical advantages of the ankle plantarflexor muscles. This reconfigurable mechanism enhances muscle effectiveness during locomotion by modulating the gear ratio of the ankle plantarflexor muscles in stance. This study also reveals many factors may contribute to the locomotor function of the human ankle-foot complex, which includes not only its re-configurable structure, but also its obliquely arranged joints, the characteristic heel-to-toe CoP motion and also the medially acting GRF pattern. Although the human ankle-foot structure is immensely complex, it seems that its configuration and each constitutive component are well tuned to maximise locomotor efficiency and also to minimise risk of injury. This result would advance our understanding of the locomotor function of the ankle-foot complex, and also the intrinsic design of the ankle-foot musculoskeletal structure. Moveover, this may also provides implications for the design of bionic prosthetic devices and the development of humanoid robots.

Keywords: Ankle, Foot, Talocrural joint, Sub-talar joint, Metatarsophalangeal joint, Ground reaction force, Moment arm, Reconfigurable mechanism

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The Influence of Intrinsic Muscle Properties on Musculoskeletal System Stability：A Modelling Study

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Abstract

The objective of this study is to investigate how the intrinsic mechanical properties of muscles 5will affect the musculoskeletal system stability. A typical musculoskeletal joint driven by a pair of antagonist muscles confined only in the sigittal plane was constructed. The dynamic characteristics of the flexor and extensor muscles induced by neural inputs were represented by three dynamic processes: neural excitation, muscle activation and muscle contraction dynamics. The muscle contraction mechanics is described using a modified Hill's model with a contractile element (CE), a parallel elastic element and a serial elastic element. Additionally, the change of muscle physiological cross-sectional area (PCSA) and pennation angle during muscle contraction were also considered. A set of dynamic simulations have been conducted by applying an external impulsive force at the distal part of the musculoskeletal system. Sensitivity analysis has been conducted to investigate the effect of the CE's force-length relationship, the CE's force-velocity relationship, the force-length relationship of the serial elastic element, the parallel elastic element and the pennation angle on the system stability. The results showed that the muscles with full intrinsic mechanical properties were sufficient to stabilize the system subject to impulsive force perturbation without reflexive changes in activations. To guarantee a self-stabilizing ability, a proper CE's force-velocity relationship, the existence of a series elastic element and a sufficient muscle co-contraction level are necessary. This study would provide insight into the intrinsic design and function of the musculoskeletal system, and also give implications for the design of bionic actuators, biomimetic robotics and prosthetic devices.

Keywords: Muscle mechanics, Musculoskeletal system, Postural stability, Intrinsic property, Force-velocity relationship, Force-length relationship

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Exploring The Collective Animal Erratic Panic and Its Application In Biomimetics

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Abstract

In biomimetics, we learn and get inspiration from animals to improve our quality of life. It is important to have better understanding on what, why, and how animal did so so that we can apply the biomimetics more effectively. Anomalous behaviors including the collective animal erratic panic (CAEP) are some of the poorly understood and potentially very important and inspiring phenomena. CAEP is not commonly noted. But it is often noticed before, during, or right after some abrupt natural disasters. There are many speculations, confusions and controversy associated with the still mysterious CAEP. CAEP could provide us with invaluable inspiration to improve our biomimetics including sensing and signal processing. CAEP would also help us to reduce our loss in lives and properties through detecting the precursors of the forthcoming natural disasters.

We have explored the important issues on 1.What is CAEP? 2. What are the major stimuli and essential mechanisms in CAEP? and 3. What wisdoms can we gain from CAEP for better understanding and to further advance our biomimetics? We have made good advances in all the three critical issues. With our preliminary results, we can explain the nearly no animal casualty in the 2004 Indian Ocean tsunami tragedy and the successful early warning in the 1975 Haicheng earthquake. We can also shed some light to the sudden disappearance of the unusually large group of sea lions at Pier 39 in San Francisco during 2009. Furthermore, we can fix the challenging twists of some anomalous animal behaviors in 2008 Wenchuan earthquake. Improved modeling and helpful appropriate experiments are needed to make further good advances. A better grasp of the CAEP can help us to improve our wisdom in biomimetics. It can also provide us with potentially vital systems for early warning of the deadly abrupt natural disasters.

Keywords: Biomimetics, Panic, Collective behavior, Animal, Stimuli

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Wake Signature and Strouhal Number Dependence of Finite-Span Flapping Wings

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Abstract

A numerical study is conducted in order to investigate the unsteady aerodynamics of finite-span flapping rigid wings. The unsteady laminar incompressible Navier-Stokes equations are solved on moving overlapping structured grids using a second-order accurate in space and time finite-difference scheme. Specifically, finite-span rigid wings undergoing pure heaving and root-flapping motions are studied. From the results presented, it is found that root-flapping wings produce wake structures similar to those of heaving wings, but with the difference that the latter wing kinematics generates larger vortices and forces than root-flapping wings; aside from this, similar wake regimes occur at comparable values of the Strouhal numbers. The numerical simulations are performed at a Reynolds number of Re = 250 and at different values of Strouhal number and reduced frequency.

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Effect of Foot Structure Morphology on Ostrich Traversing Ability on Sand

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Abstract

Ostriches, which live in the wasteland or desert, are good at scampering on sand with incredible speed. The traversing ability on sand is the combination of many factors, including the body structure, the leg's structure, the running posture, the foot structure morphology, and so on. The ostrich's feet, which contact with sand directly, play very important roles in traversing on sand for their special structure morphology.

Under the financial support by Scientific Forefront and Interdisciplinary Innovation Project of Jilin University (Grant No. 200903266), the paper studied the tissue structure and the surface covers of ostrich foot. The functions of each tissure structure of ostrich foot during traversing on sand were analyzed. The surface covers, including the skin, the scale, and the foot pad mastoid were measured by using the biological stereomicroscope, scanning electron, laser confocal microscope. The effects of different surface covers on the traversing ability of ostrich were discussed. Only two toes of ostrich foot, which reduce the contact area between foot and ground, improve the traversing speed of ostrich on sand. The toe of the third hallux inserts into sand, acting as hobnails to prevent sliding. The special surface covers on different parts of ostrich foot are helpful for wear resistance, sand-fixtion, and anti-sinkage during traveling on sand. Measuring the structure morphology of foot and analyzing their effects on the traversing ability of ostrich are very important for obtaining the mechanism of ostrich's high-speed traversing on sand.

Keywords: Ostrich foot, tissue structure, surface morphology, traversing ability on sand

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The characteristics of innervations of G. gecko's toes to motion and reception

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Abstract

As a member of robot families, climbing robots have become one of the research hot-spots in the robotic field recently and Gekko gecko (G. gecko) has been broadly seen as an ideal model for climbing robot development. But for gecko-mimic robots, one of the key problems is how to design the robot's foot. In this paper, we give an in-depth investigation into fine control and modulation of gecko's toes motion and their reception properties, provided some new ideas for foot structure design and motion control system of the gecko-robot. By using high-speed camera recording and electrophysiological method, the motion patterns of G. gecko's foot when it climbs on different oriented surfaces were observed and nerve innervations of gecko's toes to motion and reception are studied. It is found that (1) G. gecko's foot typically moved in the order of abduction, rotation and adduction on the ground, *i.e. inherent motion pattern,* but when it walked on the ceiling, its forefoot sometimes showed a different motion pattern as inward-lift, rotation and adduction, *i.e. emergency motion pattern*; (2) Five toes of the G. gecko can be divided into two motion and reception divisions, the nerve along toe T1 which innervates muscles of T1~T3 and is responsible for passing on the afferent impulses from T1~T3, and similarly the nerve along toe T5 innervates muscles of T4~T5 and is responsible for passing on the information from T4~T5. Divisional innervations make G. gecko modulate and control its movement more quickly, more finely and more concordantly. This is the foundation for gecko to adjust its motion to the changing surroundings easily and quickly. (3) G. gecko's motion and reception are modulated and controlled hierarchically, its foot adduction can be elicited using lower stimulation strength than that to elicit abduction. Hierarchical innervations of G. gecko's toes to reception are characterized by the different sensitivity in different parts of the toe: G. gecko's toe tip is the most sensitive position with the lowest discharge amplitude, and is on the inferior level of motion modulation and control; the next sensitive place is the middle part of the toe followed by the palm which has the lowest sensitivity, and the nerve fiber can only discharge when stimulation strength has built up to a certain level, but it has the highest discharge amplitude, and is on the higher level to modulate and control gecko's motion. This property is very helpful for gecko to finely modulate and control its movement. These results can serve as an inspiration and a model for robotic foot design in almost any kind of surface for climbing robots. It can also be expected that stability and reliability of the motor control system in gecko-mimic robots will be improved dramatically.

Variation in Spatio-temporal Gait Characteristics of Level, Vertical and Inverted Surface Locomotion of Stinkbugs *Erthesina fullo*

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Abstract

Many insects not only have the ability of flying but also can climb and adhere on the vertical and inverted surfaces such as wall and ceiling, even on very smooth surfaces. They climb with exceptional speed, strength and agility for their size, representing in many respects an ideal model system for the study of terrestrial locomotion. The effects of incline (level, vertical and inverted) on spatio-temporal gait characteristics (stride and step length, frequency, duty factor) were measured over a range of speeds for stinkbugs *Erthesina fullo* adhering on glass.

Surprisingly, insects perform very well when climbing vertically. That is why stinkbugs climb and adhere on cylindrical trunk better than on leaves. In the present experiments, climbing speeds ranged from 42.58 to 62.21 mm/s during level locomotion, from 44.25 to 78.12 mm/s on vertical wall and from 19.94 to 28.82 mm/s on inverted surface. In general, we demonstrate that adjustment in gait characteristics is made when insects move on differently inclined substratum. Stride length, step length and stride frequency decrease but duty factors increase gradually when stinkbugs move on different inclinations (level, vertical and inverted). Insects climb at the lowest speed on inverted surface with a decrease in stride length and stride frequency. It is easy to understand that insects pay more attention to keep stability and safety when climbing on ceilings with these adjustment in gait characteristics.

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Kinematic gait characteristics changes in patients with cerebrovascular disease during walking

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Abstract

Under the financial support by Scientific Forefront and Interdisciplinary Innovation Project of Jilin University (Grant No. 200903269), In order to make quantitative analysis of gait kinematic characteristics in the cerebrovascular disease (CVD) patients, 20 asymptomatic matched controls and 20 patients with unilateral hemiplegia due to CVD were selected from the electric power hospital of Jilin province, which could walk at least 10m independly. The relationship between the joint rotation angles of lower extremity and walking ability were analysed and compared by 3-dimensional VICON motion analysis system. Results shows compared the affected side, the patient's sound side showed significant changes in walking speed and Stance Phase. Moreover, the joint rotation angles of the affected side in CVD participants appeared positive correlated with the other side. From this experiment, it can be concluded that any part of the imbalance of the joint may affect the gait of patients.

Keywords: Cerebrovascular disease, Gait analysis, Kinematic

The influence of ratio of slope and speed on stability of walking

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Abstract

The focus of this paper was to examine the influence of ratio of slope and speed on stability of walking during normal gait. Dynamic stability was quantified by the Lyapunov exponents λ_{Max}. The data which were used to calculate λ_{Max} were recorded as subjects walked on a treadmill at 20%, 40%, 60%, and 80% of the Froude velocity, and the ratios of slope were at 0, 5%, 10%, 15% and 20%. A trend for λ_{Max} was observed that smaller λ_{Max} was at slower walking velocities and smaller ratio of slope. Smaller λ_{Max} indicates more stable walking dynamics. This suggests that smaller ratio of slope was propitious to the stability, and increasing walking velocities leads to reduction in stability.

Keywords: Gait, Stability, ratio of slope, walking speed

A minimally actuated bionic hopping robot for planetary exploration

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Abstract

Based on the mechanism of kangaroo's physical structure and gait analysis, this paper proposes a small and minimally actuated bionic hopping robot that is suitable for exploring the unstructured terrains of planets with low gravity. The robot consists of geared six-linkage mechanism with adjustable structure. Using springs, two linear actuators and solar panels, the robot can obtain hopping movements. The paper presents the design of bionic hopping mechanism, as well as the kinematics and dynamics characteristics of the bionic robot during its take-off phase. The simulation studies and the experimental results show the effectiveness of the proposed mobility.

Key words: planetary exploration, bionics, bionic robot, planetary robot, hopping robot

Behavior and dynamics of gecko locomotion: the effects of moving directions on a vertical surface

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Abstract

The study of the movement behavior of geckos on a vertical surface, including the measurement and recording of the reaction forces as they move in different directions, plays an important role in understanding the mechanics of the animal's locomotion. This study provides inspiration for the design of a control system for a bionics robot. The three-dimensional reaction forces of vertical surface-climbing geckos (*Gekko gecko*) were measured using a three-dimensional force-sensors-array. The behavior of gecko as it moved on a vertical surface was recorded with a high speed camera at 215 fps and the function of each foot of a gecko are discussed in this paper. The results show that the gecko increased its velocity of movement mainly by increasing the stride frequency in the upward, downward and leftward direction and that the speed had no significant relationship to the attachment and detachment times. The feet above the center-of-mass play a key role in supporting the body, driving locomotion and balancing overturning etc. The movement behavior and foot function of geckos change correspondingly for different conditions, which results in safe and effective free vertical locomotion. This research will be helpful in designing gecko-like robots including the selection of gait planning and its control.

Key words: gecko, three-dimensional reaction force, movement behavior, vertical surface, sensors-array

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Biomechanics characteristics research of new type of artificial hip joint

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Abstract

The structure, geometrical shape and material are the three main parts of the prostheses. This research is focused on the geometrical shape analysis. The geometrical shape of human natural femoral head is similar to an ellipse, but the artificial femoral head is rotund shaped. There is difference between ellipse and rotundity femoral head. Two models are developed and analyzed in this paper under same conditions useing Finite element analysis method. Based on the calculation results, it is shown that the ellipse shaped femoral head has similar characteristics to the natural joint than rotund model. The ellipse has more lowness stress distribution area and more small distortion magnitude than rotund shaped artificial femoral head. It should have more favourable effect to replace rotund femoral head with ellipse shaped artificial formal head.

Keywords: hip joint, prosthesis design, finite element analysis, biomechanics

Session5: Applications of Bionic Technology in Engineering

Development of Bionic Air Cooler Used in High Temperature Coal Mine

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Abstract

In a high temperature coal mine, the surface air cooler heat exchange efficiency decreases greatly beacause of high humidity and dust. In order to improve the heat exchange efficiency, the surface of the air cooler needs to be designed to reduce the dust adhesion, and improve the heat exchange efficiency. Based on the self-cleaning effect of lotus leaf, the surface of air cooler is designed, and fin and tube are processed based on the structure of lotus leaf surface. With Ansys, the cooling effect of air cooler is simulated in lab, the experiment is done to test the heat exchange effect of the common air cooler and bionic air cooler. By analysis, it can be concluded that the surface of bionic air cooler has the function of self-cleaning, the structure can increase the heat exchange efficiency, the exchange efficiency of bionic is higher above 30% than that of common air cooler.

Keywords: High temperature coal mine, Air cooler, Self-cleaning, Heat exchange efficiency

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Experimental Study on the Formation of Vortex Ring Generated by a Thin Circular Disk Yang

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Abstract

The formation process of vortex rings produced by a thin circular disk is studied experimentally in this paper. A linear motion stage with a thin circular disk is used to generate the vortex rings. Digital particle image velocimetry (DPIV) is used to measure the velocity and vorticity fields of vortex rings. The velocity field data was used to compute Lagrangian coherent structures (LCS) to demonstrate the way fluid advected during the formation of vortex ring. The results reveal a flux window between repelling Lagrangian coherent structures (rLCS) and attracting Lagrangian coherent structures (aLCS). Shear flow is entrained into the vortex by threading through the flux window. The flux window diminishes with time. The formation process of the vortex ring was completed until the flux window shut down, as the shear flow with vorticity cannot be entrained in the vortex.

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Interpretation of Beijing Model Based on Fuzzy Genetic Neural Networks

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Abstract

The global economic crisis triggers some social problems. Beijing model shows strong robustness facing the impact from economic crisis. It is more intuitional and scientific to read social formation using the natural sciences and engineering. The development of human being is similar to the evolution of human being, so Beijing model is explained by using bionics which shows that there is a complex social change and human evolution occurs. The social development forms a stable neural network model. The number of Input layer neurons of neural network was decided by the number of the factors that determine the direction of social development. The number of output neurons are decided by the number of the social properties that are made up of society, while the middle layer neurons mainly dispose information that come from input layer. Use of genetic algorithm (GA) adjusts the factors that affect the social development in order to attain higher heredity of social neural networks and use of fuzzy mathematics transfers qualitative description to quantitative analysis. That Beijing model was confirmed as mainly ascribable to action competence of the leader and spirit from our ancestor. The social genetic algorithm neural network adopts bionic technology to read Beijing model, for example fuzzy algorithm, genetic algorithm and neural network. At the same time we also analyze the cause of robustness and the method to solidify Beijing model.

Keywords: Beijing model, Bionic, Chaos, Nonlinearity, Fuzzy algorithm, Genetic algorithm neural network

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Modeling and Analysis of Hydrodynamic Characteristics of Bionic Undulating Fin Propeller Driven by Hydraulic System

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Abstract

The bionic undulating propeller driven by hydraulic system has different structure, kinematic and dynamic characteristics to that of the common bionic undulating propellers driven by other ways. The paper brings out firstly the structure and driving mechanism of bionic undulating propeller with a hydraulic system, and then set up its kinematic model, based on ruled-surface equation. With the kinematic model, changing rules of dynamic mesh for bionic fin is designed, and then the changing courses of hydrodynamic force caused by the bionic undulating fin are calculated and studied with the CFD(Computational Fluid Dynamics) method, as well as the changing characteristics of the fluid pressure field. The analysis results show that while driving by hydraulic system, the bionic propeller could produce full-baseline undulating motion, and has flexible start-up process, as well as doubled-frequency character. The bionic undulating fin driven by hydraulic system puts up flexible characteristics on both kinematic and dynamics.

Keywords: Hydraulic driven, Undulating fin, Bionic propeller, Dynamic mesh, Hydrodynamics

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Species Boundary of Bionic Theory in Provincial Domain Financial Configuration Effectiveness Analysis

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Abstract

From the perspective of finance and ecology, market, legality and government are three different ecosystems; the system functions must be clear according to bionics species boundaries. If the three borders are fuzzy, market, government and legality will occur with alienation, finance ecological balance will be broken and aroused. Financial ecosystems disorder causes the emergence of financial instability with the appearance of variants malignant alienation circumstances. The disappearance of species boundaries blur and convergence will allow the activities of financial institutions, financial product homogeneity, and thus falling into the price goal-oriented competition in which it can not extricate. The genetic algorithm in Bionics can be used in financial institutions for the entire process of new business development while working genetic code transfers effectively to conserve excellent biological genes. This difference for marketing of financial enterprises will provide theoretical support and driving force. In this paper, we enhance redundancy and efficiency bionic control and system design based on the major financial institutions and markets in analysis of Jiangxi symbiosis of the financial resources.

Keywords: Financial ecology, Bionics, Differentiated marketing, Genetic algorithm, Performance

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Bio-Inspired Philosophy in Conceptual Design of Civil Structures

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Abstract

The advent of bionics is a beginning for human being to learn from the Nature, which narrows the gap between biology and engineering. Unlike high-tech research areas, civil engineering is focused on construction of man-made structures for dwelling and transportation, such as building and bridge. By reviewing bionic architecture and bio-inspired building, the focus of this paper is to clarify what engineers need in structural design and how bionics could be an effective tool for making improvement of man-made structures. Then, bionics was classified into two categories (macro-bionics and micro-bionics) so that biologists, and bionic scholars can find specific demands from engineering field and then provide related bionic technical results and biological knowledge for conceptual design or optimization by engineers. Macro-bionic design refers mainly to the appearance, mechanism as well as the structure system from the natural world. For instance, in the conceptual design, designers can learn from the static characteristics of animals or plants for reference in order to build more reasonable and innovative bridges. Therefore, the plants and animal skeletons have been applied as the prototype when we made a design proposal for the Nanpu 3rd Bridge. With the fusion of bionics, a great breakthrough will be made for building and bridge construction. Based on the bionic engineering and biological thinking, our ultimate aim is to solve existing problems as well as to develop new bridge system for the future. We advocate for long-term cooperation from multi-disciplines in order to address difficulties of human construction in the future. The combination of biology and engineering now will answer the call to build more "Landmark" structures.

Keywords: Bionics, Engineering structure, Bionic architecture, Methodology, Bridge, Conceptual design

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The Effects of Force on the Structure Deformation of a Wing

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Abstract

This paper investigated the effects of aerodynamic force and inertial force on the structure deformation of a wing. The aerodynamic force was tested from the wind tunnel experiment. The study indicated the quantity of aerodynamic force and inertial force is equal. The maximum deformation was produced by aerodynamic force or resultant force when wing is located on horizontal situation. The study of wing structure deformation provide guide for design and optimization of flapping-wing.

Keywords: Flapping-wing, Aerodynamic force, Inertial force, Structure deformation

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Case Studies on Intellectual Property Issues for Bionics

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Abstract

Litigation problem canbecome a major worry for investors, assignees, inventors and related personnels, that even holding a quality patent may not be secure enough to be free from patent litigation. As long as the patented technology leads to considerable profits, competitors will try every possible measure to take over the market, sales order or technology, sometimes aiming to merge or probing core technology, moreover for marketing awareness or brand promotion. Accusing patent infringement through complicated technical data or wordings, patent invalidation through anticipation by 35 U.S.C. § 102 or obviouness by 35 U.S.C. § 103, or based on details such as priority dates, publicizing dates, references, filing dates,…etc. Inequitable conducts are new fashions with various tactics like attcking missing labels on embodiments,[1] unsupported spcification[2], obvious to try,[3] experiments details,[4] chemical structure's similarity upon biological efficacy,[5] similarity between dehydrated from and un-dehydrated from,[6] formulation or excipient differences,[7] even a bit late filing information disclosure statement (IDS)[8] for new references, crime fraud exception to the attorney-client privilege,[9] are common tactis in intellectual property disputs. The counteractions will be described in details with cases.

Keywords: Infringement, Doctrine of equivalence, Patent invalid, Patent anticipation, Patent obviousness

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Application of 3D Laser Scanning and Laser Cutting to Create Products through the Field of Bionics

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Abstract

This article demonstrates the feasibility of applying the tools of Bionics and Ecodesign bringing together the techniques of 3D laser scanning and Laser Cutting for product development. To implement the principles of Bionics, an analysis was performed on the characteristics of butterflies class Lepidoptera in order to obtain a proposal for a product based on its texture and wings geometry. The concepts of Ecodesign DFA (Design for Assembly) and DFD (Design for Disassembly) were used to predict the development of systems for assembly and disassembly of the product, with a minimum number of components.

Firstly, the selection of the butterfly took place, followed by 3D laser scanning of one of its wings for capturing the texture and external geometry.

The point cloud assembling was made from this scanning and also the subsequent image design, using the Geomagic® software. The vector of butterfly wing was obtained though this process and the original forms were kept.

For the creation of a union element for the wings junction, some natural elements from the body of the butterfly were digitalized, as its feet for example.

After the data surface capture, the creative process was performed in graphics software for the structural and design development. Using these graphics elements, we performed the laser cutting process, using polymeric materials as matrices.

The results obtained by scanning and laser cutting of the butterfly wings were satisfactory as long as it facilitates the connection between the process of research in Bionics as well as in Ecodesign, which proves that these techniques are suitable for obtaining great results at abstraction of shapes and textures of nature's elements, aiming to combine structural, aesthetic and functional elements to the final product.

Thus, this work shows the increasingly importance of the state of art in the creative process of products, wherein there is a need to incorporate elements of Bionics and Ecodesign.

Keywords: Bionic, 3d laser scanning, Laser cutting, Ecodesign

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Better Endurance and Load Capacity: An Improved Design of Manta Ray Robot (RoMan-II)

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Abstract

An improved design of a biomimetic underwater vehicle (RoMan-II) inspired by manta ray is presented in this paper. The design of the prototype and the swimming motion control are discussed. Instead of previously used rigid multiple degree-of-freedom linkages as fin rays, six flexible fin rays are adopted to drive two sided fins which generate thrust through flapping motions. Furthermore, in order to save the energy for long distance cruise, underwater gliding motion is implemented with this prototype. With a closed-loop buoyancy control system, the vehicle can perform gliding locomotion in water, which reduces the overall energy consumption. The vehicle can perform pivot turning and backward locomotion without turning its body. It achieves an average velocity at approximately one body length per second. As the payload capacity is about 4 kg, the vehicle is able to carry various sensors or underwater communication equipments. Initial testing shows that the operation time of the buoyancy body can last for about 6 hrs for free swimming and 90 hrs for a pure gliding. The flapping frequency, amplitude and number of waves performed across the fin's chord and wave directions can be independently tuned through motion control. This enables the prototype a good platform to study the ray-like swimming motion.

Keywords: Robotic fish, Manta ray robot, Biomimetics, Flapping, Gliding

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Effects of Bionic Non-Smooth Units on Reducing Soil Resistance to Disc Ploughing

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Abstract

Past researches have shown that the non-smooth body surfaces of soil burrowing animals help to reduce soil resistance. In this research, this concept of bionic non-smooth units was applied to disc ploughs and an experiment was conducted in an indoor soil bin to find out the effects of different non-smooth units on reducing soil resistance to disc ploughing. Horizontal force acting on the disc plough during soil deformation was measured using a 5kN sensor. Convex and concave bionic units were used as non-smooth units and the material used for making convex ones is ultra high molecular weight polyethylene (UHMWPE) which is hydrophobic. From the experiment results, higher or deeper bionic units always resulted in less soil resistance. Convex bionic units gave the highest resistance reduction reaching a maximum of 19% reduction (from 1715.36 N to 1383.65N) compared to concave bionic units. Also, a bionic unit density of 30 % gave the highest resistance reduction compared to the other two, which were either plain or had 10% density. In conclusion, the concept of bionic non-smooth units can be applied to disc ploughs in order to reduce soil resistance.

Keywords: Bionics, Disc plough, Soil resistance, Convex units, Concave units, Non-smooth surface

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Jacobian Matrix Derived from Cross Product and Its Application into High Power Joint Mechanism Analysis

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Abstract

In general, actuator size and weight increase with the actuator power, because the power mass ratio of actuators is almost constant in the same type of motors. It is difficult to realize rapid motion such as jumping and running by using only current actuator power. The aim in this research is to develop high power joint mechanism by mimicking leg mechanism of locusts. This paper describes how to develop high power in the joint mechanism. The characteristic of the joint mechanism is evaluated by using vector analysis and dynamics analysis.

Proposed high power joint mechanism consists of a closed link structure with 4 links and a spring. Linear actuators are attached to top and bottom links, and the joint angle changes by controlling the link lengths of both top and bottom. A spring is located between the output and left links, and contracts using 2 linear actuators for charging force, which is released instantaneously by one side or both sides' actuators. The joint mechanism can produce high power by this process.

From results analysis, the joint mechanism can produce high power bigger than input actuator power. Output characteristic of the joint mechanism depends on link length and link condition.

Keywords: High power joint, Locust leg structure

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Measurement of Force Produced By an Insect-Mimicking Flapping-Wing System

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Abstract

In this work, we briefly present a new version of a compact and small insect-mimicking flapping-wing system driven by a motor. Flapping performance test shows the flapper, which was powered by an onboard battery (Lithium, 3.7V, 180mAh), could produce an average thrust or lift of about 3 grams at flapping frequency of 25 Hz, and an average forward velocity of 700 mm/s in a constrained condition. Two approaches for measuring the average force of the flapper were proposed and compared with a load cell. The average thrusts measured by the two new approaches agree well with the average thrust measured by a load cell.

Keywords: Biomimetics, Beetle free flight, Wing kinematics, Flapper, Scotch yoke, linkage mechanism

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Soil Adhesion Preventing Mechanism of Bionic Bulldozing Plates and Mouldboard Ploughs

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Abstract

Soil adheres to the surfaces of soil engaging components of various tools. The adhesion of soil increases the draft and adversely affects the quality of work. For example, up to 50% of the gross energy required for tillage operations may be consumed by adhesion and friction between soil and tillage tools. Therefore, it is important to find out the ways to reduce adhesion of soil to the surfaces of various tools. Soil animals such as ground beetles stay in moist sticky soils for extended periods without soil sticking to their bodies. The soil adhesion preventing mechanisms of such animals can be used as guide for improving the scouring properties of various tools. Both the surface morphology and chemical composition of soil animal's cuticle play important role in preventing adhesion of soil to their bodies. The surfaces of mouldboard ploughs and bulldozing plates were modified based on the surface morphology of ground beetle and tested in the laboratory. Two materials such as Steel-45 and Ultra High Molecular Weight – Polyethylene (UHMW-PE) were used for convexes. The modified ploughs and plates have better scouring properties and required less draft than conventional tools. The size of convexes, their arrangement and the material of these convexes played important role in reducing adhesion and scouring soil. UHMW-PE had better scouring properties and improved wear resistances than steel-45. This paper covers the modified ploughs and bulldozing plates where UHMW-PE convexes were used for modification. The distribution of these convexes on the surfaces of bulldozing plates and mouldboard ploughs resulted in changes in mechanical characteristics and the state of water film at soil-tool interface. The unsmoothed surface morphology broke down the continuity of water film, reduced the area of contact and increased pressure at soil tool interface. The higher pressure squeezed out more water and reduced the water tension. This process was helpful in reducing friction and adhesion of soil to the surfaces of modified tools. The drafts of modified plough by bionic using UHMW-PE convexes were reduced by 25% and 30% at 3.6 km/h and 4 km/h working speeds respectively. The draft reductions in bionically modified bulldozing plates were 27%, 27% and 29% less than the conventional plates operating at 0.01, 0.02 and 0.06 m/s speeds.

Key words: Adhesion, Bionic, Unsmoothed, Mouldboard ploughs, Bulldozing plates, Draft

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Quick Detection of bacteria (E. coli) in Goat Meat Using Electronic Nose Method

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Abstract

Much attention has been paid on the foodborne illness in human beings, which is easily contaminated by bacteria or pathogens. Escherichia coli (E. coli) is one of these bacteria that commonly lives in the contaminated animal meat. There is a growing need in the food industry for pathogen detection systems that are sensitive to low levels of bacteria, specific to the target organisms, capable of yielding results at or near real time. Both contaminated and non-contaminated goat meat were tested using an electronic nose (Cyranose-320) which consists of 32 polymer sensors. We developed an electronic nose method for the rapid detection of E. coli in goat meat. Principal Component Analysis (PCA) method was employed to analyze the experiment data. E-nose has the potential for being used as a tool for rapid detection of contamination, although it is not able to detect very low concentration of the contaminant.

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Biomimetic Design and Finite Element Analysis of Stubble-cutting Discs

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Abstract

Mole rat (Scaptochirus moschatus), a soil-burrowing mammal, has high working efficiency in digging holes in soil. Its fore claws are the main digging organs. Based on the geometrical characteristics of its toe geometry, a biomimetic stubble-cutting disc was designed. In general, the performance test is necessarily conducted during product development, but it is inconvenient and time-consuming to design the structural parameters of components or testing device. In the present work，A 3D dynamic simulation model of the driven discs for cutting soil was established，which was performed to predict the effects of various cutting factors on the soil mechanical behavior. Farming soil was modeled as a non-linear elastic-plastic material with elastic parameters,such as Young's modulus, Poisson's ratio and Drucker-Prager criterion with yield stress dependent upon material property. These parameters were obtained from the laboratory experiments. A general contact algorithm was used to simulate the interaction of stubble-cutting discs with soil. A finite element analysis was performed to examine the qualities and performance of a conventional disc and a biomimetic disc. The calculation results indicated that the biomimetic disc show better performance in power saving and cutting efficiency.

Keywords: Disc, Biomimetic, Mole rat (Scaptochirus moschatus), Toe, Dynamic simulation model

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Bionic Study on Sand Erosion Resistance of Desert Scorpion

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Abstract

Desert scorpion is a typical animal living in sandy deserts, and may suffer erosion when hit by sand blowing at a high speed. The adaptability to the desert environment of desert scorpion is attributed to the natural selection over millions of years of evolution. The living habit of the desert scorpion indicates that the dorsal surface of mesosoma is the major area subjected to the sand erosion. Based on the idea of bionics and biological coupling, and taking the desert scorpion (Androctonus australis) as the research object, the mechanism of the sand erosion resistance of desert scorpion was investigated. In the present work, the morphology and structure of the dorsal surface of mesosoma were studied. From the viewpoints of both entomology and bionics, the mechanism of the erosion resistance was analyzed. Results showed that the erosion resistance characteristics of desert scorpion were realized by biology coupling. The coupling elements for erosion resistance are morphology and flexibility. Based on the bionic coupling design principle, three kinds of bionic models for erosion resistance were proposed: two single factor bionic models and a coupling bionic model, and the mechanisms of the erosion resistance models were discussed. The CFD method was applied to predict the erosion performance of the single factor bionic models, the results indicated that the bionic models exhibited good erosion resistance at low impact angle.

Keywords: Desert scorpion, Erosion resistance, Coupling bionics, Coupling elements

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Characteristic Research of Bionic Metallic Fibrous Filter

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Abstract

Monolayer stainless steel wire meshes were used to make the filter to collect particulates exhausted by diesel. The Ni-P coatings with micro- and nano-scale structure (similar to lotus) were deposited on the surface of wire meshes by the electroless plating technology. The crystalline structure and grain size of the as-deposited coatings were characterized by the X-ray diffraction (XRD). The surface morphologies and microstructure were observed by scanning electron microscope (SEM) and transmission electron microscopy (TEM). The water contact angles (WCA) were measured by optical contact angle meter (OCAM). The test results show that Bionic Wire Mesh Filter can effectively increase the collection efficiency of diesel exhaust particles and the filter back pressure was not obviously increased. The mechanisms of particulates collected were discussed.

Keywords: Bionic Metallic Fibrous Filter, water contact angles, collection efficiency, adhesion, particulates.

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Design and Test of Inter-Row Rototilling Machine

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Abstract

The inter-row rototiling machine is designed for conservation tillage mode in which traditional ridge culture is changed to flat culture, and in-row and inter-row planting with equal row spacing are conducted alternately in sequential years rather than ridge-planting year after year. High stubble is covered on the field surface after autumn harvest. In next spring, the stubble remains in place and inter-row planting is conducted. The machine is used to perform inter-row rototilling operation before planting, creating a good seedbed condition. In this paper, the arrangements of bionic universal blade for rototilling and stubble breaking on the blade rotor were studied. In addition to meeting the requirements of inter-row rototilling, the machine can also perform both stubble breaking in ridge and full-width rototilling operations by changing the number and position of the universal blades on the rotor.

Keywords: Inter-row rototilling, Conservation tillage, Bionic universal blade, Blade arrangement

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Influence of Working Parameters of Biomimetic Rolling Mills for Removing Soil from Corn Stubble

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Abstract

The rolling mills with biomimetically geometrical surfaces was designed learning from human operation for removing soil from corn stubble (human often use a stick to remove soil from corn stubble). The rolling mills with a stationary roller and a floating roller were used in the corn stubble collector. In order to remove soil from corn stubble, the biomimetic rolling mills were designed and characterized by the geometrically structured surfaces, and stubble-soil composite body can be squeezed, malaxated, pulled and pushed, impacted and sieved at the same time. Thus, a stubble-soil composite structure can be destroyed. The effects of three major motion parameters of the biomimetic rolling mills (the rotation speed of stationary roller, the speed of floating roller, and the clearance between two rollers) and the roll-type with convex construction units on the two rollers (vertical type and spiral type) on the rate of soil separation from corn stubble in working process, were examined by means of the orthogonal experiment design method for designing experiments, so the optimal combination of the major motion parameters were found. The experimental results showed that the clearance between two rollers is the most significant factor impacting the rate of soil separation from corn stubble. Furthermore, the optimal motion parameters are: the spiral type rollers, the rotation speed of 50 r/min for stationary roller, the rotation speed of 80 r/min for floating roller and the clearance between the two rollers of 30 mm.

Keywords: Corn stubble collector, Biomimetic rolling mills, Motion parameter, Rate of soil separated

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Primary Study on the Structure of Suckers of Cytister Bengalensis Aube and Biomimetic Vacuum Multi-Sucking Disc

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Abstract

As an acting equipment of vacuum absorption system , vacuum sucker or multi-sucking disc are usually used to hold、carry or suck something. In the practical application , people find a contradiction that the anti-0verturnand scraggly surface of the a single sucker with a same area and a multi-sucking disc have no synchronization. Therefore, to give attention to two or more things is always the studying direction of many pursuers. In this paper , after observing the Cytister bengalensis Aube's life habit and watching male Cytister bengalensis Aube's protergum 、 foreleg 、 midleg and female Cytister bengalensis Aube's protergum with steroscopic microscope and scanning electron microscope ,a particular structure of multi-sucking disc is found in biological world .And based on the development status quo of suck disc and multi-sucking disc in both here and abroad. We go to do some primary design and study about biomimetic vacuum multi-sucking disc.The imitation about multi-sucking disc of Cytister Bengalensis Aube gives consideration to the characters of single sucker and multi-sucking disc.

Keywords: Bionics, Vacuum sucker, Multi-sucking disc, Anti-overturn

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Study on the Application of Biological Tactile in Fast Meat Freshness Detection

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Abstract

The author aimed to explore the application of biological tactile in fast nondestructive meat freshness detection. WDW-20 electronic universal testing machine was used, chicken, pork and beef were examined, the pressure characteristic curves were analyzed and the relationship between the pressure characteristic curve parameters and the meat freshness was established. The author also analyzed the relationship between the shape of pressure characteristic curve and the meat freshness. The results indicated that in the meat pressure characteristic curve, the curve shape and a number of mechanical parameter could reflect its freshness. Also, different types of meat had different structures which led them to the different mechanical properties, different types of meat characteristic curves, the meat pressure characteristic curve shape and parameters reflected the meat freshness differently. Biological tactile can evaluate meat freshness in a few seconds. This is promising, economic, simple and practicable way of fast meat freshness detection.

Keywords: Biological tactile, TVBN, Pressure characteristic curve

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Artificial Olfactory System for Chicken Freshness Detection

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Abstract

As China's growing meat production-scale, there is the objective need to extract smell information and get the final result rapidly and steady through simulating the developed olfactory system of human being during testing meat quality.In this paper, the gas-sensitive sensor array has been optimized according to the odor of chicken and the sensor experiment. The outcome of biological olfactory research has been used to design a bionic gas collection chamber. We have also adopted RBF neural network as a pattern recognition method. Network training adopted a 10% cross-certification training program, the expected result was shown as the binary with 3 digits, the number of test training was set for 5000, and the permitted error range was about 0.001. Taking the average from 29,999 numbers of each set, 360 results as sample data were received.The fact that the accuracy of chicken freshness detection using the system is physically and chemically proved to be 96% demonstrates the feasibility of making use of AOS to detect chicken freshness

Keywords: Chicken, Freshness, Sensor, RBF neural network

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Numerical Simulation Study on Drag Reduction of Revolution Body through Bionic Dimpled Surface

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Abstract

Numerical simulation on drag reductions for the dimpled and the smooth revolution bodies were performed and compared with SST k-ω turbulence model, to explain the reasons of friction and base drag reductions on the bionic dimpled surface and the control behaviors to boundary layer near wall of the revolution body. The simulated results show that the dimpled surface arranged on the rearward of the revolution body reduces the skin friction drag by 8.05 %, the base drag by 1.9 % and the total drag by 6.24 % at Mach number 0.4; the dimpled surface reduces the skin friction drag through reducing the velocity gradient and turbulent intensity , and reduces the base drag through weakening the pumping action on the flow behind the revolution body caused by the external flow; the flow control behavior on boundary layer produced by dimpled surface displays that the low speed rotating vortexes in the dimples like vortex cushions , which segregate the external flow and the revolution body; and the low speed rotating vortexes forming in the bottom of dimples can produce negative skin friction against to the other area , which can be considered a accessional impetus.

Keywords: Engineering bionics, Dimpled surface, Drag reduction, Numerical simulation, Body of revolution

The Insect Fascicle Morphology Research and Mechanical Analysis of Bionic Needle Pierced Mechanism

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Abstract

In this paper, three kinds of insects fascicle (mosquito, gadfly, and cicadas) were studied and the fascicle surface morphology and distribution was observed through scanning electron microscopy. The heights of the six parameters of sawtooth were analyzed quantitatively and discussed. After comparing the three types of fascicle in micro-structure size and shape, the experiment results show that there are obviously differences among the three mouth fascicle morphological structures. Triangular sawtooth are all clearly visible in the three kinds of insect fascicle, in which the mosquito has the smallest microstructure, the gadfly ranks middle, and the cicada has the largest one; microstructure of mosquitoes and gadfly tilt to the rear part of the fascicle, while the microstructure of cicada is symmetric on bottom corners. Based on non-smooth surface structure of fascicle's obvious principles of drag reduction effect, the model of drag reduction bionic syringe is proposed. Bionic drag painless needles were designed and the simulated needle piercing power is also measured. Bionic needle surface microstructure can help reduce the contact area of the area, form rolling

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Casting method of Rib-like bionic non-smooth surface on the Centrifugal pump impeller

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Abstract

it is already confirmed that the riblet on the shark skin have relationship with drag reduction. However, the processing technology of such non-smooth structure on complex surface is very difficult. In this paper, the casting method of rib-like non-smooth surface on the type of 200QJ50-26 centrifugal pump impeller was investigated. First, according to designing request, rib-like non-smooth structures were sculptured using knife and ruler on the hard rubber pad. Second, heat-resisting lacquer was spread evenly on the two side of the riblet and made them natural drying. Third, utilizing the characteristic of rubber, the rib-shape rubber was adhered to the sand moulding surface of impeller according to the shape of it. Finally, cast into form. This kind of technology made bionic non-smooth surface formed easily, especially in complex impeller surface. Except, compared with the technology of EDM (Electron Discharge Machining) and machining technology, it also have the characteristics such as good stability, never produce crack and so on.

Keywords: Bionic non-smooth, Rib-like, Drag reduction, Casting, Process method

The Porous Ceramics For Biomedical Applications

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Abstract

At present, materials with a stochastic pore structure are attracting great interest because of their wide application as filters for fluid purification and separation, catalyst carriers, artificial bones, etc. In this work, we have studied the effect of pore morphology on the mechanical behavior of partially stabilized zirconia. The objects of investigation were ZrO_2 ceramic samples, their porosity ranged between 2 and 60%.

The increasing volume of porosity decreases tetragonal phase content almost by 2 times. It is stipulated by the growing of crystallites and absence of compressive stresses in high-porous media, which stabilize the tetragonal phase. Ceramic with the porosity more than 20% has the complex stress-strain behavior. In Fig. 1, the exponents ***k*** measured from the slopes of the linear segments in stress-strain curves in log-log coordinates are plotted against porosity. The data points for ***k*** are well fitted by three straight lines; there exists some critical porosity value at which the deformation of the porous material radically changes: the second exponent of the power function (much larger than that in the initial state) appears. So, the material was split into two subsystems, which deform in different ways under stressing. In this ceramics during sintering were formed rod-like structures with their micro-mechanical instability and considerable macro-deformation as structural elements, which may be realized in the elastic area. It has been found out also the correlation between the sizes of crystallites, fractal dimension and porosity, which associated with transition of the isolated porous structure to the continuous one and the porosity of 20%, corresponds to the first percolation threshold.

It have been shown that morphology of pores and mechanical behavior of ceramic with rod-like structure are very similar of natural bone. It have been carried out citotoxic tests of such ceramic which were shown that viability of cells can reaches up to 100%.

Evaluating biological systems for their potential in engineering design

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Abstract:

A team of biologists, engineers, and cognitive scientists has been working together for the past five years, teaching an upper level undergraduate course in biologically inspired design where half the class of forty students are biologists and other physical scientists and the other half are engineers (mechanical, materials, industrial, others). From this experience, we provide insights on how to teach students to evaluate biological systems for their potential in engineering design. We have found that at first, students are not familiar with developing their own question since, in most engineering design classes, the problem is prescribed along with clients who would like to have them solved. In our class, we challenge the students with defining a significant problem. The students with common challenges then are placed together in an interdisciplinary team with at least one biologist and one engineer. A detailed problem decomposition follows, identifying the hierarchy of systems and clearly specifying functions. This is essential for the next step of analogical reasoning. Analogical reasoning as applied to BID is a process of matching biological functions to engineered functions and transferring functions and mechanisms from biology to engineering. For each desired function, students may ask: what mechanisms does nature use for achieving the function? This question guides the exploration of the wealth of knowledge in biology by asking them to clearly define the function of interest, then search for natural processes that perform this function. To expand on this search space, the students next make a list of the same function performed by other organisms for a comparative analysis to deepen their understanding and extract key biological principles. Students then invert the function and identify keywords to search. They also must refer to general biology books to identify key organisms that perform the function the best (and hence are included in textbooks). Using databases, such as the Web of Science functions, they can try to select the 'best' articles. If one is lucky, a single biological system may serve as a near perfect match to lead to a successful BID. However, the most innovative designs are built from more than one biological system, something that evolution cannot always do. We call these compound analogies. At this point, the design iteration can take on a different approach, namely solution based rather than problem based. Here, the team takes a natural system and asks, how can this biological principle improve an engineered design or function. These twin processes: solution vs problem-based approaches both have led to innovative and creative design concepts in this interdisciplinary class.

Effects of Electric Stimulation of Basal Nucleus onMovement in *Gekko gecko*

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Abstract

Animals have wonderful locomotion abilities, especially those that can move on 3-dimensional, complex terrain. The remarkable motion capability of geckos has made them the hot spot for research. In this paper, in order to develop bio-robot gecko, we studied the motor function of the basal nucleus and other stuctures in gecko's.brain.

we use the electriccal stimulation methods to study the motor function of the gecko's basal nucleus.The experiments includes two parts: the lightly anesthetized test（ n=17）and freely moving, awake test（n=10）. In the acute experiment (anesthetized test), we investigated the cortex dorsalis, nucleus accumbens, spherical nucleus, nucleus of the diagonal band of Broca and the septum. Results showed that electrical stimulation of medial striatum, dorsal striatum and central striatum could induce gecko's tongue flicking, about 5 s later after simulation(Rate＞80%). Electrical stimulation of ventral part of nucleus septalis medialis and medial forebrain bundle could induce gecko's legs moving(Rate=50%). Electrical stimulation of the ventral part of nucleus septalis lateral and lateral forebrain bundle could induce geckos' backbone bending (Rate=30%), and electric stimulation of the ventral part of dorsal ventricular ridge and nucleus accumbens could induce respiration deepen and accelerated (Rate=50%).

In the chronic experiment (freely moving, awake test), electrical stimulation was delivered through implanted electrodes in the basal nucleus and the septum. Results suggested that electrical stimulation of medial striatum could induce gecko's tongue flicking (toward the same side of stimulation), about 3 s later after stimulation, which similar to the acute experiment; electrical stimulation of the septum could induce the head turning ipsilateral.

Our study suggested that gecko's basal nucleus played an important role in the gecko's locomotion.

keywords: *Gekko gecko*；basal nucleus；electric stimulus；body movement

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Top Microneedles: Mosquito Fascicle *

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Abstract

Needle injection is one of the most popular methods of drug delivery. Insertion of a traditional hypodermic needle into a patient's skin not only causes significant pain but also induce skin damage. Recently, a novel technology that employs arrays of "microneedles" for transdermal drug delivery has attracted much attention due to its painless and minimal invasion. Unfortunately, either fracture failure or buckling of the artificial microneedles is the major obstacle preventing their wide applications.

However, there exists in nature an ultimate painless "microneedle" system, i.e., the mosquito fascicle. It never exhibits fracture or buckling failure although the ratio of the length to the diameter of the fascicle reaches over 60. The mouthparts of female mosquitoes (males do not feed on blood) have evolved into a proboscis comprising the feeding fascicle and the labium that sheaths the fascicle in its gutter-like structure. During blood feeding, the labium buckles and remains on the surface so that only the fascicle actually penetrates the skin.

Here, we used a high-speed video camera to observe the penetration process. It is found that the most important parts of the fascicle used for penetration are the central, straight needle-like labrum and two microsaw-like maxillae with nanosharp teeth. When the tip of the labrum penetrated into the skin surface, the mosquito started to use its microsaw-toothed maxillae with an oscillation movement to saw more deeply into the tissue of the skin. It is possible that the progressive increase of the penetration depth and, consequently, the frictional force between the fascicle and the skin tissue causes the mosquito to decrease its oscillation frequency.

We measured for the first time the dynamic penetrating force of the fascicle into human skin using a specially designed micro-Newton force measurement device. The measured insertion forces ranged from 6 μN to 38 μN with a mean value of 16.5 μN (80 experiments), which is almost the same as the average body weight of the studied mosquitoes. This force is three orders of magnitude smaller than the minimum force reported to pierce human skin with an artificial microneedle. The mosquito proboscis, functions highly efficiently to penetrate into skin and let the insect become a high skill skin diver. This could potentially inspire humans to design a more efficient artificial hypodermic microneedle or a microdevice for minimally invasive surgery.

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A Study of Urban Housing Demolition Compensation System in China based on Evolutionary game theory

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Abstract

Along with the rapid process of urbanization in China, the adjustment of urban spatial layout will accelerate urban housing demolition conflicts. Unreasonable compensation system is one of the most important reasons of the urban housing demolition problem. The evolutionary game theory is applied in order to produce a comprehensive analytic framework for solving such problem. Based on this theory, evolutionary game model is established and the evolutionary stable strategy (ESS) is obtained under different circumstances. The results show that, household can get higher compensation when they take aggressive strategy, and driven by economic interests, local government may take the high hand in order to complete demolition mission. At last, in light of these problems, several suggestions are given in order to improve the compensation system.

Keywords: urban housing demolition, compensation system, evolutionary game theory

An artificial eye Actuated by IPMC Actuator

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ABSTRACT

Ionic Polymer-Metal Composite (IPMC) is one of the most promising EAP actuators. It has many advantages such as light weight, no noise, large displacement, a low driving voltage when compared with the traditional actuators. Typically, the strip of the perfluorinated ionic polymer membrane bends toward the anode (in the case of cation exchange membranes) under the influence of an electric potential. Many scholars are attracted by the above-mentioned excellent feature, and carry out a lot of researches in aspects of its application. For instance, limited-angle motor was developed by Kentaro Takagi and an autonomous robotic fish for mobile sensing was designed and manufactured by Xiaobo Tan. We find that the eye motion can be applied to IPMC motion. According to our survey, there are only a few movable eye structures available. And using IPMC as an actuator offers a new method. Therefore, in this paper, we will report an artificial eye actuated by IPMC. It consists of body structure and control system. The entire body structure is composed of a transparent hemispherical shell, artificial eye, spring (or no spring), IPMC and a baseboard. The shell is fixed on the surface of the baseboard. The space between them is filled with water, supplying a wet condition for IPMC. One end of IPMC is fastened by the groove of the baseboard, with copper sheets on its both sides as electrodes. The other end of it is used for actuating the artificial eye. IPMC will bend under a low voltage. When there is no spring, the device can make the artificial eye realize one dimensional motion. And with a spring, the bionic eye can move in two dimensions. The weight of the artificial eye is about 1.2g. Based on the previous experiments, we found that sine wave and square wave have a better effect on the motion of IPMC than others. In order to facilitate the use of the device, we also design a signal generator as a control system, which can be powered by lithium battery and generate sine wave and square wave by different frequencies and voltages. In addition to this, it can display the wave style, the value of frequency and voltage. It is found that it can satisfy our expectations. In these experiments, we have confirmed that IPMC can actuate the bionic eye effectively. In the future, we will study what influences artificial eye's motion property and optimize it.

Keywords:IPMC, artificial eye, signal generator, actuator

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Biological Colour Application in Bridge Engineering

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Abstract

A variety of organization forms of colours, such as protection colour, warning colour and so on, exist in nature. By introducing the related research of colour psychology and bionics, this article tries to resolve some of the existing bridge engineering issues, and will likely lead to a prospect of new materials and ideas. By colour selection and matching, the workers feel good during the bridge construction process to some extent, ensuring safety production. Navigation safety can be promoted by applying warning colour during the operational process. In the event of an inclement weather like very hot and cold, it may weaken the impact on bridge structure by just changing the colour appearance. In war and emergency cases, changing the colour appearance may avoid risks and meet the requirements of military security..The study of biological colour applications in all respects will help promote the design and operation of the bridge toward the safe, durable and beautiful appearance suiting the environment.

Key words: Colour, Bridge engineering, Security, Aesthetics

Hydrodynamic study of a self-propelled robotic fish

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Abstract

A novel method based on force-feedback control technique to make sure the robotic fish is self-propelled is briefly introduced. The flow field in the wake of the self-propelled robotic fish is quantified by particle image velocimetry. To compare the differences in wake between the self-propelled and the non-self-propelled robotic fish, the flow patterns generated by a robotic fish fixed to a place in a water tank during flapping its tail and also a robotic fish fixed to a carriage while towing this carriage through a water tank are also investigated. The results in the three cases are also compared with results of a live fish. It indicates that the wake of a self-propelled robotic fish is relatively close to that of a live fish.

Keywords: Robotic fish, Force-feedback, Self-propulsion, PIV

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Bionic Creatology and Total Innovation Management (TIM)

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Abstract

In this paper the author describes the role of Bionic Creatology in Total Innovation Management (TIM). Creatology refers to the consolidated , comprehensive multi-disciplinary science of creativity and innovation that includes several sub-disciplines for consideration of all studies of various aspects of creativity and innovation. From this view point Bionic is a sub-discipline of Creatology (Bionic Creatology or Nature-based Creatology) .Total Innovation Management (TIM) is a new extensive organizational / managerial Creatology approach to the traditional innovation management . Bionic Creatology can play an important role in innovation engineering processes and another sub-systems of the TIM via two main ways: Technological Bionic Creatology (TBC) and Managerial Bionical Creatology (MBC).

Keywords: Bionic, Creatology, Total Innovation Management (TIM), Technological Bionical Creatology (TBC), Managerial Bionical Creatology (MBC)

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Enhancing Innovation through Biologically Inspired Design

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Abstract

Mixing upper level undergraduates majoring in engineering with those majoring in biology, we have devised a course on biologically-inspired design (BID) that provides practical training in methods and techniques that facilitate the identification and translation of biological principles into solutions for human challenges. The challenges of interdisciplinary courses generally, and the specific challenges of fostering exchange among biologists and engineers lead us to define these learning goals: (1) basic knowledge of successful examples of BID,, (2) interdisciplinary communication skills, (3) knowledge about domains outside of their core training, (4) a uniquely interdisciplinary design process, and (5) how to apply existing technical knowledge to a new discipline**.** We developed the following course components to meet the key learning objectives: BID Lectures; Design Lectures; Found object exercises; Quantitative assessments; Analogy exercises; Research assignments; Interdisciplinary Collaboration, Mentorship; Idea Journals and Reflections. We will provide an extensive description of these elements, which we have chosen to incorporate based on our own experience with interdisciplinary communication, as well as findings from cognitive science regarding how students actually learn. This 15 week course is organized using assignments of increasing complexity that allow students to learn and apply essential skills of BID methodology and practice. Early exercises, which combine lectures, group discussions and individual assignments, have these objectives: 1) allow students to develop the necessary inter-disciplinary communication and research skills to facilitate their design project work; 2) expose students to ideation and design skills that will encourage them to work outside of their comfort zone; 3) practice the analogical reasoning skills that facilitate the successful search for and application of relevant biological concepts. This initial portion of the course stresses that BID occurs at the early phase of a design process and that identifying solutions from the biological domain requires that students have a sufficient breakdown of their problem combined with sufficient biological knowledge to suggest appropriate mappings between problem and solution. Two primary barriers are a lack of appreciation for how the evolutionary "design" process differs from human design, and the use of different terminology for describing similar processes in biology vs. engineering. We describe some teaching practices and activities that allow students to overcome these difficulties. The course culminates in a group project, which is a detailed conceptual design including a preliminary analysis of expected performance, value, and feasibility. A unique feature of the course is that it represents the efforts of not only biologists and engineers, but also contributions from cognitive scientists engaged in understanding human cognition and

creativity. Our course strategy has been deeply influenced by findings in that field. We have studied the activity of classroom participants for the last three years, examining the processes they use, and intermediate and final design representations. Analysis of this has yielded a number of observations about the cognitive process of biologically inspired design that may provide insights regarding how to enhance BID education, as well as provide useful insight for professionals in the design field.

A New Method of Biomimetic Pattern Recognition and Its Application to Iris Recognition

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Abstract

As one of important research areas of artificial intelligence, pattern recognition has been widely applied in many fields. However, traditional pattern recognition uses "optimal separating" of different kinds of samples in the feature space as main principle, which may lead to recognition error for the samples untrained in learning process. Biomimetic Pattern Recognition (BPR) based on Multi-Dimensional Space Biomimetic Informatics uses "optimal coverage" of same kind of samples in the feature space as main principle, which is much closer to the function of human being than traditional pattern recognition. It can overcome the weak point of traditional pattern recognition. In addition, multi-resolution analysis techniques have played a very important role in developing feature extracting methods, but there lacks of BPR under multi-resolution analysis framework to induct the application of pattern recognition. In this paper, a new method of BPR under multi-resolution analysis framework is proposed. In the Framework of multiscale BPR, the multiscale features are extracted by multiwavelets transform and local Histogram of Oriented Gradient descriptor is used to get differential and robust representation at different scales. The super dimensional space covering of feature space is constructed by Self-Organizing Map (SOM) clustering and distance projecting distribution in the feature space of same kind of samples. During recognition phase, the sample to be identified is judged whether it belongs to different scale covering sets and inner product with a kernel function to decide the sample whether it comes from the same kind. In experiment, to verify the effectiveness, the proposed method is applied to iris recognition. Receiver Operating Characteristic (ROC) curve and Probability Density Function (PDF) of same and different class samples are given based on JLUIRIS database. Experimental results show the proposed method is effective for pattern recognition application.

Keywords: Multi-Dimensional Space Biomimetic Informatics, Biomimetic Pattern Recognition, GHM multiwavelets, Histogram of Oriented Gradient, Iris recognition

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Study of mechanical properties and topological structure for tree network and its application

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Abstract

This paper reports on the mechanical properties and topological structure of some typical tree leaves and the application in the wind turbine blade. Several areas are explored:

(i) The vein network, material and mechanical performance of some tree leaf such as palm, using experimental and simulation methods.

(ii) The shape and topological structure study of the tree leaf and wind turbine blade to explore their similarity and their self-adaptation function to environment.

(iii) The application of plant leaf network into wind turbine blade design.

In this paper, some leaf species were collected, and their network models were built to explore the mechanics of reinforcement performance under the natural wind loads. The results indicate that the deformation and strain energy of the natural leaf network are optimal, and the vein pattern of plant leaf has evolved into a kind of steady structure in order to adapt to the change of environmental stress. And it is interesting to find that the elastic modulus of palm tree leaf is up to 15 GPa, which demonstrates a very good mechanical performance to resist the wind load.

We found that the plant leaf shape, its inner structure and mechanical environment etc are similar to the structure of wind turbine blade. And a good way to reveal their similarity is to study their topological structures, and the work done in this aspect shows that the plant leaf topological structure is similar to blade topological structure, especially the vein network-the medial axis pattern similarity, which indicates that plant leaf networks play important role in their mechanical support system and have the adaptivity to avoid any deformation caused by the hostile environment.

It is well-known that the wind turbine blades are normally made of glass fiber composite materials. While the material lay out can be designed with the intention to satisfy the design object, which supply a practical means to imitate the networks of plant leaf into blade design. Thus, in this paper, 1.5MW blade was built to verify this idea. We changed the lay out in some parts of the blade. With the numerical simulation, It shows that the maximum Von-Mises stress reduced, which has a great effect on the blade fatigue performance always produced in the blade root part, and number of their occurrences outnumbered the fatigue stress decreased as well. On the other hand, the deformation and strain of the blade fiber was always in the safe range. It is concluded that the fatigue and feasibility performance of the blade was improved.

Study on the Starting Distance of the Mining Subsidence Based on theKey Stratum Theory

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Abstract

The relationship between the starting distance of mining subsidence and the first breaking span of key stratum was studiedaccording to the key stratum theory. The difference, including time and dimension, between experimental result of the starting distanceand the first breaking span was analyzed first, and then the theoretical computation method for the starting distance was put forwardbased on the analysis of the difference of them.

Keyword: subsidence, starting distance, key stratum, breaking span

Study on drag reduction characteristic around bodies of revolution with bionic non-smooth surface

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Abstract

Smooth and non-smooth bionic models were tested with oil flow visualization. This technique was one of convenient way to show separated flows in complicated air flow. Through analyses of oil flow spectrum, characteristics of flow flied around bodies of revolution can be obtained: flows had same characters in all sections in flow direction, i.e. flows were symmetry. Non-smooth structures affected flows around them dramatically. Marked particles stimulated in every dimple concave unit, where had small cutting stresses. In addition, adjacent parts were influenced by these structures and striping zones with same dimension of dimple diameter showed stress stimulated in these places. However convex dome units had same flow appearance with ball-shape objects. Separated flows exited behind every single dome. Distinct oil stimulation parts appeared in models' head, shoulder part and tail of the models which had strong curvature changing. But compared with the smooth model, oil stimulation zones in three non-smooth models had changed a lot both in width and position, which absolutely resulted from these little non-smooth structures. These changed showed that flows separated much later in non-smooth models than smooth, especially in models No.1 and No. 3, having non-smooth structure in tail, which had the smallest oil stimulation zones showing the effects of postponed separated point. So these models had smaller pressure drag.

Key words: Oil flow visualization, Drag reduction, Non-smooth surface, Bionic

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