of adhesion will lead to unavoidable time to failure decreasing induced by internal action of electrocorrosion, ponderomotive forces and low-strength of these permanent connections.

1. A.C. Tam, Rev. Mod. Phys., 1986, v.58, p. 381

2. Волкенштейн С.С., Дайняк И.В., Хмыль А.А. Сравнительная оценка альтернативных методов контроля качества и диагностики монтажных конструкций «п/п кристалл - подложка». «Доклады БГУИР», №2, 2016 г., с. 51-55.

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PROCEDURE FOR DESIGNING OPTIMIZED ACTUATORS OF THE ROBOTS USING BIOLOGICAL OBJECTS

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The urge for individual mobility has led to the development of airplanes, trains and cars, which are much faster locomotion systems than human legs. Nevertheless, pedal locomotion systems and humanoid robots are main focal points of worldwide research in biologically inspired robotics. Biomimetical robots are developed by engineers and scientists in the life sciences by joint integrative analysis (i.e.,combining different analytical layers) of the construction and functionality of animal locomotion systems and the transfer of the construction principles to technical fields.

Currently, the development of “walking machines,” i.e., pedal locomotion, dominates the research of biologically inspired locomotion systems. The known solutions for “walking machines” range from uniquies for fundamental research to series manufacturing of commercial products for the entertainment industry. From bipedal to octopedal constructions, almost all biological prototypes have been constructed by engineers. Due to the dedication of BERNS of the University of Kaiserslautern, the walking machines catalogue (www.walking-machines.org) has given an excellent overview of available walking machines worldwide for many years. The motivation for this research direction is of very different nature [1].

In the literature several methods of techniques finding technical solutions, sets of software products supporting the process of technical systems design and a selection of technologies to be implemented are described. Nevertheless, having well developed tools of the analysis, these methods frequently have no effective solving tools for problems.

A new approach of special problem-solving methods at the initial design stages is presented. The methods are based on analysis and the combination of technical or biological objects and a legged robot. Described techniques allow us to create several new legged robots. A new class of micro robots and a new class of legged mechanisms is chosen to present the possibilities of the method. Merging the kinematics of a salamander with the kinematics of an octoped allows us to develop a new eight legged robot with only three actuators. Combining a flying insect and a piezotransducer with extremities supplies a new object - the piezomicrorobot. For movement of multi-legged robot through a pipe we use the trawling wave of the Holothouria.

Biological objects as prototypes are used preferably due to the fact that during millions of years of evolution their principles of motion have been developed contemplating minimal energy wasting. [1]

The essential design stage, which is discovering ideas for new functional principles of technical systems, is almost entirely based on the know-how of the engineer[2, 3]

The subject of our work is the development of new functional principles of legged robots.

By using a principle of work and kinematics of biological prototypes it is possible to develop new ideas for a moving robots improvement. Some biological objects use unusual ways of moving of the extremities to obtain the necessary trajectory. They change form and sizes of the body to create the necessary movement of legs.

By applying the introduced method new robots can be created. It is based on the combination of biological and technical objects. The developed method is based on the well-known principle known as the combination of alternative systems. It enables the transfer of characteristics and structure from one object (i.e. its kinematics) to another object leading to new desirable characteristics or optimisations of existing technical objects[4].

Multy-legged mobile systems classification is represented .In our opinion, there exist only 4-5 main principles of functioning of biologic objects for providing the necessary trajectory of the legs movement. The suggested classification and the analysis of biological prototypes have allowed us to create some new mobile robots. In known walking robots the several actuators for moving each leg are used. Our robots principle difference allow to use each actuator for moving several legs. Thus, we managed to minimize number of actuators at the robot. It opens the new possibilities of the considerable miniaturization of mobile robots in future.

Thus, the ability to develop new functional principles of legged robots (i.e. new motion principles, new kinematics etc.) is provided. The analysis is used to realize the transition from known (in biological objects) to new (for legged robots) forms of motion.

Minimization of number of actuators multi-legged robots can be reached through [6 7 8 9]:

- use of periodical changing the shape of the body of the robot in horizontal dimension (salamander, lizard)
- use of periodical changing the size of the body of the robot in vertical dimension (flying insects)
- use of anisotropy of friction (snake)
- use of periodical character or feature of trawling wave (holothouria)
- use of multidimensional resonance swinging of elastic extremities (mosquito)
- reducing of number of bearing legs (kangaroo, basilisk, birds)

For micro robots it is possible to use a principle of movement as at Polichetae . In this biologic object the legs have no actuators and no degrees of freedom relative to a body. They are rigidly attached perpendicularly to a surface of a body, so they move and incline together with deformation of this surface. To create necessary trajectory of a distal end of a leg, Polichetae and Holothouria uses deformation of the case as trawling wave. The number of legs-needles is not limited, but number of the actuators enabling deformation of the case, is minimal. It is possible to create tiny robot with a plenty of legs and with low number of small-sized actuators. We have developed the moving robot-probe with 100 legs and with only four actuators - "Holothourobot. It can be used in medicine for minimal invasive surgeries.

The salamander bends its body in a horizontal plane and due to this, moves the body relative to the points of support (Fig.3). By using deformation of a robot body in a horizontal plane it is possible to provide it's moving due to a minimum number of actuators. The actuators are not connected to legs and they are necessary only for deformation of a robot body. Having as few as three actuators it is possible to provide moving of the robot with eight legs "Eightleggedrobot".

Some flying insects create resonant oscillations of the wings due to periodic change of the form and the sizes of the rigid body (Fig.4). These insects' muscles are connected not to the wings, but to the walls of a rigid body and deform it. Deformation of body turns into swinging of wings. It is possible to create the moving robot at which the case vibrates, and legs have no actuators. The necessary trajectory of distal part of a leg is formed due to excitation of the high-frequency swinging in proximal part of an elastic curvilinear leg and due to mechanical transformation of these swinging in low-frequency. We have developed essentially new tiny moving system "Minchrobot". As the case and as the actuators the, piezo-bimorph-plate is used. It can cover 1 meter per 1 second.

Summary

The analyses of biological objects and alternative technical systems offer new opportunities for the engineers. That analysis is an indistinct provisional approach of solving a technical problem. In further stages of the design process the engineer formulates precisely this solution and verifies it by means of mathematical modeling and calculation.

The described technique does not supply convertible constructive drawings immediately, however, it provides new solutions with new ideas. Furthermore, it is possible to develop essential new legged robots with minimal number of actuators.

1. Zimmermann, K.: An approach to the modelling of biological and technical movement systems. 1. International Conference on Motion Systems, Univ. Jena, 1997.
2. Lysenko; V.: Algorithmische Methode für die Entscheidung auf Anfangsstufen beim Entwerfen. 41. Internationales Wissenschaftliches Kolloquium. 1996. TU Ilmenau.
3. Lysenko, V: Method for improving actuators by modelling the motion of an earthworm. 1. International Conference on Motion Systems, Univ. Jena, 1997.
4. Lysenko, V.; Zimmermann, K.: New procedure for designing optimized technical systems with use of biological objects. 1st Intern. Conf. on Design & Nature, Udine, Sept. 2002, WIT Press Southampton 2002, pp.115-122.
5. Becker, F., Minchenya, V., Zimmermann, K., Zeidis, I. Single Piezo Actuator Driven Micro Robots for 2-dimensional Locomotion. Aachen: Electro. Proceedings of Workshop on Microactuators and Micromechanisms, 2010.
6. V. Lysenko, K. Zimmermann, A. Ahranovich. Method for designing new technical systems based on a Transparent Morphological Cube with the use of the tree-like classifications. – 53. Internationalen Wissenschaftlischen Kolloquium. 2008. TU Ilmenau.
7. V. Lysenko, W. Minchenya, K. Zimmermann. Minimization of the number of actuators in legged robots using biological objects

(Bionically Inspired Robotics Biomechanics). 52. Internationalen Wissenschaftlischen Kolloquium. 2007. TU Ilmenau.
8. On Mechanics of Bristle-Bots – Modeling, Simulation and Experiments. Lysenko V., Becker F., Zimmermann K. Zeidis I. Konferenz ISR/ROBOTIK Berlin 2014.
9. A Vibration-driven Robot for the Inspection of Pipelines., Lysenko V., Becker F., Zimmermann K., 58th IWK in Ilmenau. 2014.

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СВОЙСТВА КОМПОЗИТА НА ОСНОВЕ СВЕРХВЫСОКОМОЛЕКУЛЯРНОГО ПОЛИЭТИЛЕНА

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Введение

Волокна из сверхвысокомолекулярного полиэтилена (СВМПЭ) обладают очень высокой устойчивостью к УФ – изучению, химическим воздействиям и погодным условиям [1-3]. Удельная плотность СВМПЭ составляет примерно 0,98 г/см^3, модуль Юнга до 200 ГПа. Сочетание этих свойств, придает волокнам характеристики, превосходящие подобные параметры для стальных волокон. Таким образом, все это делает композиционные материалы из СВМПЭ незаменимыми в конструкциях со статической и динамической нагрузкой. Молекулы СВМПЭ состоят из длинных линейных цепочек полиэтилена с относительно слабыми межмолекулярными связями (10-20 кДж/моль). При производстве таких материалов применяются модифицированные технологические процессы с использованием сополимеров [3-5].

Регулирование молекулярной массы продукта осуществляется изменением соотношения компонентов катализатора, и их концентрацией в процессе синтеза. В работе исследуется композит из сверхмолекулярного полиэтилена и связующего блок-сополимер стирол – изопропен – стирол.

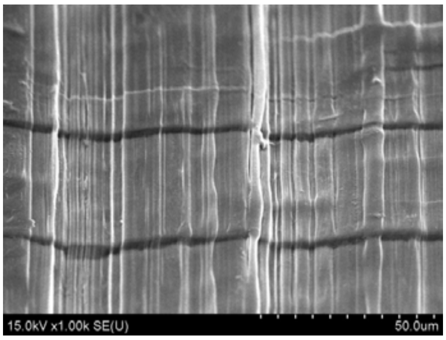
Целью данной работы являлись исследования морфологии композита на основе СВМПЭ и магнитного резонанса, а также установление возможности применения данного композита в радиоэлектронике.

Методика и результаты эксперимента

Исследования морфологии образцов проводились с помощью сканирующего электронного микроскопа фирмы «Bruker». Измерения проводились при значениях ускоряющего напряжения от 6,4 до 30 кВ.

Исследования магнитного резонанса проводились на специализированном малогабаритном анализаторе ЭПР «Минск 22» при комнатной температуре. Рабочая длина волны — 3 см. Максимальное значение индукции магнитного поля — 450 мТл, частота модуляции - 30 кГц. Для калибровки интенсивности сигналов от объектов исследования использовался образец из монокристалла рубина ($Al_2O_3:Cr^{3+}$). В процессе измерений дополнительный контроль стабильности работы спектрометра осуществлялся путем измерения калибровочного материала - двухвалентного марганца ($MgO:Mn^{2+}$).

На рисунке 1 представлено строение композита.

а) 

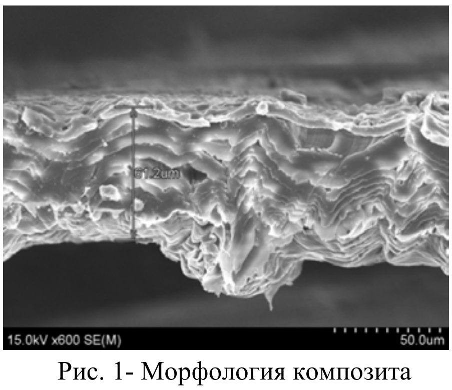
б) 

Рис. 1- Морфология композита
а) - вид сверху,б) - сечение