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## MECHANICAL AND THEORETICAL ENGINEERING

**L. O. Shtripling, E. G. Kholkin, V. V. Merkulov**  
**Improving efficiency of installation for disposal**  
**of oil-contaminated soil at low temperatures**

**Omsk State Technical University, Omsk, Russia**

The article discusses some features of the method of reagent encapsulation in conditions of negative temperatures. An installation layout has been created that makes temperature measurement of the encapsulated material in the process of reagent encapsulation. During the experiment, the duration of maintaining the temperature necessary for preparing the next portion is determined. A comparison is made of the methods for supplying carbon dioxide to the installation during reagent encapsulation. As a result of the experiment, a more profitable way of supplying carbon dioxide to the installation is determined.

Keywords: Equipment for decontamination, oil-contaminated soil, reagent encapsulation.

**A. M. Lasitsa, V. G. Churankin,**  
**T. A. Churankina, R. O. Dzivilskiy**  
**The effect of TiN coating on stress distribution in carbide**  
**cutting inserts in treatment of austenitic stainless steels**

**Omsk State Technical University, Omsk, Russia**

The article discusses the stress distribution on a cutting insert made of WC 92 % + Co 8 % during processing of austenitic stainless steel. The calculation of the components of the cutting force is performed, the finite element method is used to calculate the stresses and displacements of the material of the triangular cutting insert TPUN 160338. It is shown that the resulting stresses exceed the yield strength of the material and stress relaxation occurs in a cobalt bond. The presence of a TiN coating leads to a more uniform stress distribution and reduces stresses to values not exceeding the yield strength.

Keywords: cutting tool, carbide material, stress distribution, stainless steel, WC, TiN.

**A. S. Serkov<sup>1</sup>, V. B. Masyagin<sup>1</sup>,**  
**R. L. Artyuh<sup>1</sup>, L. B. Serkova<sup>1</sup>, V. V. Akimov<sup>2</sup>**  
**Studying stress-strain state of gear billet using mathematical**  
**models depending on clamping forces in 3 and 6 cam self-**  
**centering chucks**

<sup>1</sup>**Omsk State Technical University, Omsk, Russia**

<sup>2</sup>**Siberian State Automobile and Highway University,**  
**Omsk, Russia**

The article discusses the results of studies of the 3D model of the gear wheel by the finite element method (FEM) in the stress-strain state (VAT). The model is in a state of static equilibrium in the presence of various basing mechanisms. The novelty lies in the study of the effect of clamps on gears with various basing schemes in 3 and 6 cam chucks. Physical experiments are obtained (photomechanics).

Keywords: non-rigid gear blank, finite element method, mathematical modeling, mathematical model, 3D modeling, three-dimensional model, APM FEM, Compass 3D, stress-strain state (VAT).

## ELECTRICAL ENGINEERING

**R. N. Khamitov<sup>1</sup>, V. V. Anikin<sup>1</sup>, V. Z. Kovalev<sup>2</sup>, A. O. Paramzin<sup>2</sup>**  
**Research of operation of electrotechnical complexes of electric**  
**centrifugal pumps units for variations in external temperature**  
**effects**

<sup>1</sup>**Omsk State Technical University, Omsk, Russia**

<sup>2</sup>**Yugra State University, Khanty-Mansiysk, Khanty-Mansi**  
**Autonomous Okrug – Yugra, Russia**

The article investigates the functioning of the electrotechnical complex of the electric centrifugal pump installation in case of

variations in external temperature influences. A mathematical model of the analyzed complex is created taking the thermal non-stationary processes into account. It is also proposed to build an electromechanical system with an adjustable submersible electric motor with a subblock of parameter identification and a block for the estimation of state variables. This will allow considering external temperature influences during the control.

Keywords: electric centrifugal pump installation, submersible electric motor, mathematical model, thermal non-stationary pump.

**A. V. Ded, V. A. Tkachenko**  
**Algorithmic implementation of calculation of energy**  
**consumption and determination of the class of energy efficiency**  
**of elevators**

**Omsk State Technical University, Omsk, Russia**

The article presents the results of the implementation of the developed algorithm for calculating the energy consumption of elevators in order to determine the class of their energy efficiency. The algorithm is based on methods for measuring the actual energy consumption of elevators in use or released into circulation. The practical implementation of the generated calculation algorithm is performed in the Microsoft Visual Studio software environment. The generated program report complies with the requirements of the current regulatory documentation GOST R 56420.2-2015 «Passenger elevators, escalators and conveyors. Energy characteristics».

Keywords: basic cycle of the elevator, measurement of consumed electricity, elevator drive, productivity, energy efficiency class, energy characteristics.

**T. V. Kovaleva, O. O. Komyakova, N. V. Pashkova**  
**Resonance in alternating current traction network**

**Omsk State Transport University, Omsk, Russia**

The article provides an analysis of electromagnetic processes in an alternating current traction network of electric railways taking into account its distributed parameters that determine wave processes, which are one of the causes of resonance phenomena. Resonances in the traction network negatively affect the quality of voltage and current, amplify interfering effects on adjacent devices and can cause damage to electrical equipment. The results of the calculation of the minimum resonance lengths of the sections of the traction network and the multiples of the voltage and currents depending on the frequency of the supply voltage make it possible to assess the influence of the length and parameters of the line, such as the load on the presence of resonances.

Keywords: resonance, electromagnetic processes, traction network, distributed parameters line, alternating current, electric railways.

## INSTRUMENT ENGINEERING, METROLOGY AND INFORMATION MEASURING EQUIPMENT AND SYSTEMS

**V. V. Bolotov, E. V. Knyazev, I. V. Ponomareva, V. E. Roslikov**  
**Morphology and gas response of nanocomposite structures**  
**based on irradiated ensembles of multi-walled carbon**  
**nanotubes and titanium oxide**

**Omsk Scientific Center of Siberian Branch of Russian Academy**  
**of Sciences, Omsk, Russia**

Nanocomposite structures are obtained on multi-walled carbon nanotubes pre-functionalized with argon ions and non-stoichiometric titanium oxide supported by magnetron deposition (MWCNT/TiO<sub>x</sub>). The morphology of the ensembles of individual MWCNT/TiO<sub>x</sub> composite nanostructures functionalized with argon ions and the gas response of these nanostructures to NO<sub>2</sub> and H<sub>2</sub>S are studied. Irradiation of MWCNT layers leads to an increase in their resistance by a factor of 1.5. A change in the resistance of a MWCNT/TiO<sub>x</sub> nanocomposite upon gas adsorption repeats a similar change in the resistance of an ensemble of irradiated MWCNT, which demonstrate gas-sensitive properties characteristic of a material with p-type conductivity —

a decrease in resistance during exposure in an oxidizing gas and an increase in resistance in a reducing gas.

Keywords: multi-walled carbon nanotubes, titanium oxide, nanostructures, irradiation, gas response.

**V. V. Bolotov, V. A. Sachkov**

**The influence of oxygen as impurity substitution defects on the electronic structure of binary graphene**

**Omsk Scientific Center of Siberian Branch of Russian Academy of Sciences Omsk, Russia**

The paper is devoted to the study of the effect of oxygen as an impurity substitution defect in single-layer and double-layer graphene planes on the electronic properties of these structures. The van der Waals interaction is studied for the electronic properties of paired graphene planes of the substitution type for an impurity oxygen atom. Calculations of the «ab initio» electronic zone structure of the studied objects are made. The results obtained are applicable to the analysis of the zone structure of multi-wall carbon tubes containing defects.

Keywords: nanosensoric, carbon nanotubes, two-layer graphene, band structure, point defects, «ab initio».

**V. Yu. Kobenko, S. O. Frolov, V. I. Talalayev**

**Development of algorithm for segmentation of handwritten text using masks**

**Omsk State Technical University, Omsk, Russia**

The work highlights the problem of extracting handwritten text on the image for further recognition. Describes common methods of segmentation, allowing to solve this problem: method of color image analysis the binary image segmentation method of fixing level, as well as, a method for the separation and analysis of circuits. The proposed algorithm for text segmentation based on the use of the mask of the original image to simplify the segmentation of text in images with a non-monotonic background. Also the comparative analysis methods is done.

Keywords: segmentation of handwritten text using a mask, removing the background image.

**V. P. Belyaev<sup>1</sup>, M. P. Belyaev<sup>2</sup>,**

**L. G. Varepo<sup>3</sup>, P. S. Belyaev<sup>1</sup>, V. V. Pavlinov<sup>1</sup>**

**Preferences substantiation for non-destructive diagnostic methods selecting pores diffusion coefficient in block products**

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<sup>2</sup>Military Educational and Scientific Centre of the Air Force

N. E. Zhukovsky and Y. A. Gagarin Air Force Academy, Voronezh, Russia

<sup>3</sup>Omsk State Technical University, Omsk, Russia

The metrological analysis of non-destructive methods determined the diffusion coefficient in block products formed from porous materials is considered. The methods are based on both various types of pulsed effects on the products flat surface and their reaction monitoring in terms of electromotive force changes of an electrochemical converter. The developed technique obviates long transducer calibration stage for each new porous material and diffusing polar solvent, increasing the analysis efficiency. The analyzed methods application areas are substantiated in the context of ensuring acceptable accuracy including in the presence of pronounced anisotropy of properties.

Keywords: porous materials, block products, diffusion coefficient, non-destructive testing, pulse methods.

**R. B. Burlakov**

**Hall element with two Schottky barrier contacts Al-p-Si**

**Dostoevsky Omsk State University, Omsk, Russia**

Way of the fabrication and results of studies of electrical and photoelectric characteristics of the Hall element with two current contacts and two Hall potential contacts on one surface of the silicon plate and two contacts Al-p-Si with the barrier Schottky on inverse surface of the plate, are considered. Explored Hall element

has a simple technology of the fabrication and possesses extended functional possibilities.

Keywords: way of the fabrication of the Hall element, silicon p-type, Schottky barrier contacts Al-p-Si.

**A. V. Zubar<sup>1</sup>, K. V. Kaykov<sup>1</sup>,**

**R. N. Khamitov<sup>2</sup>, I. G. Volf<sup>3</sup>**

**Development of multiple-factor simulation model of accuracy assessment in passive optical-electronic system for determination of parameters of targets of armored arms**

<sup>1</sup>Omsk Tank-Automotive Engineering Institute, Omsk, Russia

<sup>2</sup>Omsk State Technical University, Omsk, Russia

<sup>3</sup>Perm Military Institute of the National Guard Troops of the Russian Federation, Perm, Russia

In the article the solution of a problem of assessment of accuracy of determination of coordinates of objects is stated by the system of technical sight intended for application as a part of an aim and observation complex of a sample of armored arms. The essence and the main stages of calculations of the developed simulation model are disclosed. The feature of this model is the possibility of calculation of distribution of an error of measurement of coordinates on all volumes of measuring space, and its form, and the sizes depending on mutual position of the video cameras, their internal parameters and accidental components influencing process of measurements.

Keywords: modeling, accuracy assessment, determination of coordinates, system of technical sight

**M. L. Ivanov<sup>1</sup>, D. K. Avdeeva<sup>1</sup>,**

**M. M. Yuzhakov<sup>1</sup>, S. A. Rybalka<sup>1</sup>,**

**Guo Wenjia<sup>1</sup>, I. V. Maksimov<sup>2</sup>,**

**M. V. Balakhonova<sup>2</sup>**

**Methods of program analysis of high-resolution electrocardiogram recorded using hardware-software complex based on nanosensors**

<sup>1</sup>Tomsk Polytechnic University, Tomsk, Russia

<sup>2</sup>Tomsk National Research Medical Center of the Russian Academy of Sciences, Tomsk, Russia

<sup>3</sup>Siberian State Medical University, Tomsk, Russia

The paper aims to consider the software methods used for detection of elements of high-resolution electrocardiographic (ECG) signals recorded using a nanosensor-based hardware and software complex. To achieve the aim, the study employed the following methods: correlation analysis, bi-directional filtering, first-order derivative, and correction algorithms. For cases when the automatic detection of elements was made with an error, an additional algorithm for manual correction of QRS elements has been developed.

Keywords: QRS complex detection, ECG analysis, adaptive filtering.

**P. M. Korusenko**

**The study of morphology and electrochemical properties of supercapacitor working electrode based on multi-walled carbon nanotubes doped with nitrogen**

**Omsk Scientific Center of Siberian Branch of Russian Academy of Sciences, Omsk, Russia**

In this work, we study the morphology, structure, specific surface area, conductivity, and electrochemical properties of the supercapacitor working electrodes prepared based on undoped and nitrogen-doped multi-walled carbon nanotubes (MWCNTs). It is shown that nitrogen-doped MWCNTs have a larger specific surface area and conductivity than MWCNTs due to the presence of structural defects and functional groups on their surface. Using scanning electron microscopy, it is shown that the electrodes formed based on undoped and nitrogen-doped MWCNTs have a porous structure, which ensures the penetration of electrolyte into the volume of the electrodes. A comparative analysis of the electrochemical characteristics of the supercapacitor electrodes in a unipolar acid electrolyte H<sub>2</sub>SO<sub>4</sub> is carried out. Using cyclic voltammetry, it is shown that the high specific capacitance of the

electrode based on nitrogen-doped MWCNTs at low scan rates is due to the additional contribution of Faraday processes involving structural defects, functional oxygen-containing and nitrogen-containing groups on the surface of nanotubes.

Keywords: multi-walled carbon nanotubes, supercapacitors, specific capacitance, structure, Raman spectroscopy.

**P. M. Korusenko**

**The study of morphology and electrochemical properties of nanocomposite based electrode consisting of multi-walled carbon nanotubes and Sn/SnO<sub>x</sub> metal oxide particles**

**Omsk Scientific Center of Siberian Branch of Russian Academy of Sciences, Omsk, Russia**

The morphology and electrochemical characteristics of an electrode based on a SnO<sub>x</sub>/Sn@MWCNTs composite consisting of multi-walled carbon nanotubes (MWCNTs) and metal oxide particles (Sn/SnO<sub>x</sub>) with a core-shell structure are studied. This composite shows good electrochemical characteristics as the anode material for lithium-ion batteries, providing 1494 mAh/g as the first discharge capacity and 634 mAh/g discharge capacity after 30 charge/discharge cycles (72 % capacity retention). The stable characteristics of such a material are due to the high interfacial adhesion between functionalized MWCNTs and Sn/SnO<sub>x</sub> nanoparticles, as well as their unique gradient structure.

Keywords: multi-walled carbon nanotubes, nanocomposite, core-shell structures, electrochemical properties.

**S. N. Nesov**

**The effect of vacuum annealing on structure of composites based on multi-walled carbon nanotubes and tin oxide formed using the magnetron sputtering method**

**Omsk Scientific Center of Siberian Branch of Russian Academy of Sciences, Omsk, Russia**

Using the method of X-ray photoelectron spectroscopy (XPS) and transmission electron microscopy, the effect of heat treatments under ultrahigh vacuum on the structure and chemical composition of composites based on multi-walled carbon nanotubes (MWCNTs) and tin oxide formed using the magnetron sputtering is studied. The processes occurring in the composite at various temperature conditions of heat treatment are determined. It is shown that vacuum annealing of the composite at a temperature of 500 °C leads to homogenization of the composition of the metal oxide component due to the disproportionation of oxide Sn (II) with the formation of a more stable oxide Sn (IV). With an increase in the temperature of vacuum annealing to 800 °C, oxide Sn (IV) is reduced to tin metal upon interaction with carbon. The results obtained in this work can be used for directional modification of the structure of composites based on nanostructured carbon materials and tin oxide.

Keywords: multi-walled carbon nanotubes, tin oxide, composite, X-ray photoelectron spectroscopy, vacuum annealing.

**S. N. Nesov**

**Comparative analysis of structure and chemical state of nitrogen-doped multi-walled carbon nanotubes**

**Omsk Scientific Center of Siberian Branch of Russian Academy of Sciences, Omsk, Russia**

Using the method of X-ray photoelectron spectroscopy (XPS), a comparative analysis of the structure and chemical state of multi-walled carbon nanotubes doped with nitrogen during their synthesis, as well as by high-dose irradiation with nitrogen ions, is carried out. It is shown that the chemical state of nitrogen in the walls of MWCNTs doped with various methods differs significantly. It was found that the use of ion irradiation allows

one to obtain MWCNTs with a higher nitrogen concentration in the structure of the outer walls. However, there is a significant increase in the degree of imperfection of the crystal structure of the walls of carbon nanotubes and the formation of oxygen-containing functional groups. The features of the chemical state of nitrogen in the walls of MWCNTs using various alloying methods are established. The results obtained in this work can be used to develop methods for modifying the electronic structure of carbon nanostructured materials.

Keywords: multi-walled carbon nanotubes, X-ray photoelectron spectroscopy, nitrogen doping, ion irradiation.

**V. A. Sachkov**

**Effect of defects such as vacancy with oxygen and adsorbed oxygen on electronic structure of graphene plane**

**Omsk Scientific Center of Siberian Branch of Russian Academy of Sciences Omsk, Russia**

The article is devoted to the study of the effect of vacancy-type defects with an oxygen atom attached to the graphene plane depending on the concentration of defects. Numerical calculations are performed using the «ab initio» method for a graphene plane with defects in the zone electronic structure. The analysis of the dependence of the main parameters of the zone electronic structure: the width of the band gap, and the mobility of free charge carriers depending on the concentration and type of defect. The conditions of formation of the forbidden zone in the zone structure are studied. The results obtained are applicable to the analysis of the zone structure of single-wall carbon tubes containing defects.

Keywords: nanosensoric, carbon nanotubes, graphene, band structure, point defects, «ab initio».

**Yu. A. Stenkin, D. V. Sokolov**

**The effect of annealing temperature on gas sensing response of non-stoichiometric manganese oxide IV**

**Omsk Scientific Center of Siberian Branch of Russian Academy of Sciences, Omsk, Russia**

Layers of non-stoichiometric manganese dioxide are obtained and their gas-sensing responses are studied. The temperature range of isochronous annealing has been determined, in which the obtained layers are highly sensitive to hydrogen sulfide, nitrogen dioxide, ammonia, and toxic organic gases — acetonitrile and phenol. The enhanced selectivity to organic gases by thermal annealing of oxide layers has been established.

Keywords: manganese dioxide, isochoric annealing, gas response.

**Yu. A. Stenkin, D. V. Sokolov**

**Selective gas detection using composite oxides based on Co<sub>x</sub>O<sub>y</sub>/MnO<sub>2-z</sub>**

**Omsk Scientific Center of Siberian Branch of Russian Academy of Sciences Omsk, Russia**

The article presents the results of a gas response study of oxide semiconductor layers based on cobalt and manganese oxides Co<sub>x</sub>O<sub>y</sub>/MnO<sub>2-z</sub> with different Co/Mn ratios. An analysis of the experiments shows that there is certain synthesis condition in which selectivity to hydrogen sulfide of composite oxide layers is high. In the detection of hydrogen sulfide, the composite Co<sub>x</sub>O<sub>y</sub>/MnO<sub>2-z</sub> (2,5Co/5Mn) has the maximum gas response.

Keywords: manganese dioxide, cobalt oxide, sensor, gas response.

**Anniversaries**

**V. V. Makarov**

**To the anniversary of Victor Potapov**