



## Engineering Science

“Vesnik Hrodzenskaha Dziarzhaunaha Universiteta Imia Ianki Kupaly.

Seryia 6. Tekhnika”

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### Study of structural differences in non-crystalline objects by X-ray diffraction analysis

*[Issledovanie strukturykh razlichii v nekrystallicheskikh ob"ektakh  
metodami rentgenostrukturnogo analiza]*

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**Abstract.** The introduction discusses the structure of crystalline and non-crystalline materials, as well as the effect of modifiers of various chemical composition on the structure of composite materials formed on an organic and inorganic matrix. The aim of the study was the dependence of the intensity of the scattered x-ray radiation on the degree of ordering of atoms and compositions of non-crystalline objects. The object of research was the dependence of the structure factor of the scattered radiation and the radial distribution function of atomic density (RDFAD). In the main part, the following tasks are considered: analysis of X-ray diffraction patterns of non-crystalline objects with various compositions and impurities; the derivation of the formula for calculating the function of the radial distribution of atomic density according to x-ray diffractometry; the effect of the sample on the radial distribution function of atomic density for the same type of substance (glass, polymers); establishing the transition of the formula for calculating the radial distribution function of atomic density with increasing degree of atomic ordering in the Paterson formula. It was established that this function is sensitive to changes in the concentration of impurity atoms. If a non-crystalline sample with an anisotropy of the degree of atomic ordering is studied, then this anisotropy can be analyzed by changing the orientation of the sample relative to the x-ray incident on it. Studies on the structural features of nanocomposite materials based on polyolefins using the proposed technique made it possible to establish structural changes in the amorphous part of the modified polymers. In conclusion, it was shown that an increase in the degree of intermolecular ordering leads to an increase in the physicochemical characteristics, which is in good agreement with the available data from other scientific sources, in which an increase in the values of wear resistance, hardness, and tensile strength of polyolefins modified with nanodispersed diamond particles is noted.

**Keywords:** structure factor, radial distribution function of atomic density, Zernike–Prince formula, Paterson function, polymer composite.

**Tables – 1. Images – 6. Bibliography – 4 titles**

**Composite materials based on regenerated thermoplastics  
for the manufacture of metal-polymer rollers of belt conveyors**

*[Kompozitsionnye materialy na osnove regenerirovannykh termoplastov  
dlia izgotovleniia metalopolimernykh rolikov lentochnykh konveierov]*

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**Abstract.** The introduction shows the relevance of the use of polymer and composite materials in the production of structural elements of metal-polymer rollers used in the construction of belt conveyors for the mining and construction industries. The main directions for improving the rollers of belt conveyors are indicated. The aim of the work was to assess the effectiveness of the implementation of the multi-level modification methodology when creating composite materials based on regenerated matrices for the manufacture of elements of metal-polymer rollers of belt conveyors. The main part discusses methods for implementing the methodological approach of multilevel modification of thermoplastic matrices to form the structure of composite materials with specified parameters of operational characteristics. A substantiated choice of technologies for introducing nanosized carbon-, silicon- and metal-containing compatibilizers into the structure of the “thermoplast – thermoplast” and “thermoplast – thermoplastic elastomer (elastomer)” composite materials depending on the functional purpose of the products made from it is presented. The results of the study of the parameters of stress-strain, tribological and adhesive characteristics, as well as the resistance of the developed nanocomposites to the effects of thermal oxidative degradation, confirming the feasibility of using individual approaches to the formation of the structure of the nanocomposite for the manufacture of a specific product with specified performance parameters are presented. The prospects of using regenerated thermoplastics of the polyolefin class to produce functional composites for the manufacture of structural elements of metal-polymer rollers of belt conveyors is shown, as evidenced by the results of testing a pilot batch of rollers in belt conveyors used in the technological processes of extraction and processing of mineral raw materials at the enterprises of JSC Belaruskali. In conclusion, the main results obtained during the study and recommendations on the practical application of the developed compositions of composite materials based on regenerated thermoplastics in various designs of metal-polymer rollers of belt conveyors are presented.

**Keywords:** composite material, metal-polymer roller, belt conveyor, multi-level modification, regenerated polypropylene.

**Images – 4. Bibliography – 12 titles**

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**Abstract.** In the introduction, the object of research has been mentioned – tension and deformations of welded joints of steel parts from low carbon steel obtained by gas shielded arc welding. The article aimed to study the changes in visible deformations and residual stresses of welded joints obtained by gas shielded arc welding of low-carbon steel parts St08kp, followed by gas-dynamic cooling of the heat-affected zone with an inert gas. Scientific novelty consists in the study of the strength characteristics of welded joints obtained by using the developed method to control the cooling rate of the zone of thermal influence – gas-dynamic cooling. Practical significance is observed in the study of the strength characteristics of welded joints, one of the most important indicators of welded structures in all areas of industry. The main part of the article presents the results of mathematical and physical analysis of changes in the deformations and tension of welded joints obtained by semi-automatic gas shielded arc welding with subsequent gas-dynamic cooling, specifically: determination of the mathematical dependence of the effect of changes in the cooling temperature of welded joints on the formation of visible linear and angular deformations; determination of the mathematical dependence of the influence of visible angular and linear deformations of butt welded joints on the formation of residual stresses in welded structures; description of the fundamentals of the method of gas-dynamic cooling of the heat-affected zone for managing the cooling process of welded joints; the results of changes in the apparent angular deformations of welded joints obtained by semi-automatic gas shielded arc welding of flat parts made of St08kp steel under various regimes of gas-dynamic cooling of the heat-affected zone are presented; presentation of the results of a study of the strength characteristics of samples under static stretching and bending, conclusions are drawn about the results. In conclusion, results are described about fulfilling the purpose of the study, changing the visible deformations and stresses of welded samples during gas-dynamic cooling of the heat affected zone of the weld, a theoretical justification for changes in the basic strength characteristics of welded samples is made.

**Keywords:** arc welding, shielding gas medium, visible deformations, heat-affected zone, residual stresses, gas-dynamic cooling, strength, yield strength, fracture, static stretching, static bending, elongation, plastic deformation.

**Tables – 3. Images – 8. Bibliography – 18 titles**

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**Effect of electroerosive modification of the surface  
of a single and winding wire tool on its performance  
when sawing glass using polishing material**

[Vliianie elektroerozionnogo modifitsirovaniia poverkhnosti  
odinarnogo i svitogo provolochnogo instrumenta  
na ego ekspluatatsionnye pokazateli pri raspilivanii stekla  
s primeneniem svobodnogo abraziva]

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**Abstract.** In the introduction, the object of study is indicated – a wire tool. The main concepts are defined: winding wire tool, polishing material, sawing, modification. The aim of the study is an experimental assessment of the influence of the step of winding of two saw wires, as well as electroerosive modification of its surface performance indicators when sawing glass samples using polishing material, in particular, on the intensity of their sawing, the roughness of the cut surface and its width, as well as on tool wear resistance. The main part describes the developed methodology for conducting experimental studies to assess the influence of the step of winding of the wire saw and electroerosive modification of its surface performance tools indicators when sawing glass samples using polishing material. The usage of winding of two thin wires saw with electroerosive modification of its surface is proposed in order to create favorable conditions for the delivery of abrasive grains to the processing zone, which increase the productivity of the operation of sawing materials using polishing material. It was found that surface modification of the tested wire tools in all cases leads to an increase of sawing samples intensity based on the results of the experiments. From a comparative analysis of the obtained experimental data, it follows that surface modification of the tested instruments increases their wear resistance. Surface modification of the tested tools in all cases leads to an increase in the roughness parameter  $Ra$  of the sawn surface of the sample. Its smallest increase is observed in a single wire tool, and the largest – in a winding tool. It was established that the step of winding of the wire saw formation affects the width of the cut on the sample. Surface modification of the tested tools in all cases leads to an increase in the cut width on the sample. In addition, it was found that the modification of the initial surface of the tested tools leads to an increase in their wear resistance. In conclusion, the main results of the experimental studies of the effect of electroerosive modification of the surface of a single and winding wire tool on its performance when sawing glass using polishing material are given.

**Keywords:** electroerosive modification, winding wire tool, polishing material, sawing, wear resistance, cut width.

**Tables – 1. Images – 6. Bibliography – 11 titles**

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**Synthesis of an unmanned aerial vehicle control  
based on a synergetic control theory**

[*Sintez upravleniia bespilotnym letatel'nym apparatom  
na osnove sinergeticheskoi teorii upravleniia*]

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**Abstract.** In the introduction, an object of investigation is pointed the optimal controller for the terminal control task of an unmanned aerial vehicle, represented by a multidimensional nonlinear dynamic object in the pitch plane. The result of an analytical review of methods and approaches of control theory for the synthesis of control systems is presented. A method for solving the problem of control synthesis for nonlinear dynamic objects is proposed. The theoretical foundations of the synergetic theory of control are given. The aim of the study is to synthesize the control law of an unmanned aerial vehicle, which allows to improve the stabilization of transient quality indicators. In the main part, a mathematical model of the longitudinal motion of an unmanned aerial vehicle in the pitch channel is presented, the formulation of the synthesis problem is formulated. The requirements for the optimizing quality functional, the type of macro variables of the first and second levels are determined. The control law is obtained as a function of the coordinates of the state of the system, ensuring the movement of an unmanned aerial vehicle with a given normal acceleration. At the same time, the set quality indicators are provided (regulation time, overshoot) and asymptotic stability of movement is guaranteed. Simulated mathematical modeling of the developed control law with known parameters of the aircraft was carried out. The analysis of the synthesized control law is carried out. For a comparative analysis of the model of the stabilization system of an unmanned aerial vehicle, built on the principles of a synergetic control theory, we used the model of the stabilization system of an unmanned aerial vehicle taking into account the gear ratio change mechanism and

feedback on the angular velocity sensor. In conclusion, it is concluded that it is advisable to use the method of analytical design of aggregated controllers for the synthesis of control laws of systems described by multidimensional nonlinear differential equations.

**Keywords:** synthesis, optimal controller, synergetic control theory, invariants, quality indicators, unmanned aerial vehicle.

**Tables – 1. Images – 4. Bibliography – 7 titles**

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### **Nutrition for children suffering from phenylketonuria**

*[Obosnovanie i obogashchenie produktov pitaniia  
dlia detei, stradaiushchikh fenilketonuriei]*

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**Abstract.** The introduction gives a brief description of nutrition in phenylketonuria (disease associated with metabolic disorders). Phenylketonuria is the only of all hereditary diseases, manifestations, which can be completely cut short with the help of a special low-protein diet. If the low-protein diet is not observed, this disease is accompanied by the accumulation of phenylalanine and its toxic breakdown products. This leads to a severe defeat of the central nervous system (CNS), manifested, in particular, in the form of a violation of mental development (phenylpyrovinograd oligophrenia). Children with phenylketonuria and the possibility of enriching food for such children are the subjects of research. The aim of the research is qualitative study of problems and features of nutrition for children suffering from phenylketonuria. Main features of nutrition during phenylketonuria were revealed on the basis of normative documentation and scientific literature in the main part. Main problems arising during the organization of diet therapy for children with phenylketonuria are identified and also formulated in the framework of the research. The most promising for enrichment products were identified to expand the range of products and eliminate the shortage of minerals and vitamins in food. Also additives obtained by drying plant raw materials are offered to increase the biological value of products. The schemes of reception of powder from dried courgettes with use of various technological equipment, as well as its organoleptic characteristics are given in the article. The conclusion describes proposals for improving nutrition for children with phenylketonuria. Based on analysis, for expansion of assortment can be chosen bakery products on the basis of rice and corn flour, additionally enriched with calcium and vitamin D.

**Keywords:** phenylketonuria, nutrition analysis, courgette powder, bakery products, drying.

**Tables – 1. Images – 2. Bibliography – 20 titles**

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### **Tomato powder as a promising supplement for the activation of baker’s yeast in the production of crackers**

*[Poroshok tomatov kak perspektivnaia dobavka  
dlia aktivatsii khlebopekarnykh drozhdzhei pri proizvodstve krekerov]*

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**Abstract.** In the article, indicators of crackers quality produced in a laboratory experiment on the basis of composite mixtures, which include wheat flour of the first and second grade and large fruit tomato powder in dosages of 1, 3, 5, 7 % of the flour under different conditions of yeast activation were analyzed. The introduction substantiates the necessity to include secondary resources of production and processing of fruit and vegetable products into the bakery products recipe both for the development of functional products and to optimize testing and improve the quality of finished products. Characteristic of properties of tomato powder as the source of micronutrients, dietary fibres and antioxidants, which are physiologically active functional ingredients have been done. In the main part, the results of research of the technological properties of composite mixtures based on wheat flour of the first and second grade and large fruit tomato powder in dosages of 1, 3, 5, 7 % of the flour are showed. Positive influence of explored vegetable powder on the rising power of yeast and on the dough ball blurriness was proved. Samples were baked and results of the study of organoleptic and physicochemical indicators of finished cracker products based on composite mixtures are showed. Capability of preactivation of baking yeast by the tomato powder suspension was explored. Baking of flour products with reduced doughing time due to activation of a yeast suspension with tomato powder was done. The experiment found a slight decrease in the mass of raw gluten and its relaxation in samples of composite mixtures compared to the control. Positive influence of tomato powder on gaseous activity of yeast was revealed. During the experimental baking some organoleptic characteristics (taste, aroma, color) of finished products with the inclusion of vegetable powder were being improved while maintaining of physical and chemical parameters within the normalized limits (humidity, wetness, acidity). Researches, that were made, showed the effectiveness of tomato powder use during functional crackers producing, what will allow to expand the choice of producing production and use secondary products of vegetables production and reduce the time of doughing. The field of application of the research results is confectionery and bakery production.

**Keywords:** flour composite mixtures, tomato powder, cracker, yeast activation, physical-chemical indicators, functional food, technological properties.

**Tables – 3. Images – 4. Bibliography – 26 titles**

“Vesnik Hrodzenskaha Dziarzhavnaha Universiteta Imia Ianki Kupaly.

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### **Magnetic methods in the processes of processing of agricultural raw materials**

[*Magnitnye metody v protsessakh pererabotki sel'skokhoziaistvennogo syr'ia*]

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**Abstract.** The introduction indicates the object of study – products of processing agricultural raw materials in animal husbandry and crop production. The existing problems in the processing of agricultural raw materials are noted. The aim of the work is to carry out a comprehensive analysis of the state of the problem and the prospects of using magnetic methods in the processing of agricultural raw materials in animal husbandry and crop production. The main part describes the magnetic apparatus used to implement magnetic methods in the agricultural sector, the essence of the magnetic method and a brief theory. A formula is given for calculating the magnetic force acting on charged ions in a flow. The achievements using magnetic methods in the processing of agricultural raw materials in livestock and crop production in Russia, the USA, Canada, Turkey, China, Iraq are shown. Information is given on theoretical studies substantiating the mechanism of the influence of an electromagnetic field of low frequency and extremely low frequency on plant seeds, animal feed, activated water, yeast, as well as information on works with the analysis of existing magnetic processing devices used in the agricultural complex is given. It is shown that the main condition for the implementation of the primary physicochemical effect of magnetic fields on water systems is the movement of a liquid or biological objects through polygradient magnetic fields. In conclusion, the problems of applying magnetic methods in agricultural processing processes are shown: the lack of a unified theory explaining the effect of magnetic fields of various configurations and intensities on biological objects; the effects of the magnetic field on biological objects have not been investigated. Scope of the results: increasing the efficiency of the processes of production and processing of agricultural products in animal husbandry and crop production.

**Keywords:** magnetic methods, magnetic apparatus, agricultural raw materials, theoretical and experimental activities, modifying effect.

**Images – 1. Bibliography – 32 titles**

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**Control of the course of the pasta test in forming press matrixes  
by using confuser-diffuser inserts**

[*Upravlenie techeniem makaronnogo testa v formuiushchikh matritsakh pressa  
s pomoshch'iu konfuzorno-diffuzornykh vstavok*]

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**Abstract.** The introduction substantiates the relevance of research and development. It is noted that a significant drawback of pressing pasta on screw presses is the unevenness of the extrudate exit speed along the die plane, which leads to an increase in the amount of waste in the form of scraps and, ultimately, to a decrease in the productivity of the press. One of the effective ways to solve this problem may be to install special inserts in the matrix wells that regulate the channel resistance to viscous flow. The goal of the work is to increase the working efficiency of forming matrices due to controlled additional deformation with equalizing the speed of pasta dough by installing special inserts in the matrix wells. The inserts containing compression zones (confuser), expansion (diffuser), and a cylindrical transition between them are technological in manufacturing designs. Several designs are proposed, including in the form of a symmetrical insert-insert, as well as asymmetric inserts with an internal cavity such as direct-flow or counter-current (reverse) Venturi tubes. A series of preliminary (evaluation) experiments was carried out to check the theoretical assumptions using the MIT-2 small pasta press. It was experimentally confirmed that the installation of confuser-diffuser inserts in the matrix wells made it possible to equalize the local resistance by the matrix area, stabilized the dough flow (equalized pressing speed), and thereby increased press productivity. The hypothetical mechanism for achieving a set of useful effects for the production of pasta from the use of inserts consists in a smoother transition of the dough into the forming holes of the die with its additional compaction, plasticization and heating. This ensures a decrease in hydraulic resistance when forcing the dough through the holes of the inserts, and also improves the quality of pasta and increases the productivity of the pasta press.

**Keywords:** pasta dough, pressing out speed, matrix, confuser-diffuser insert, Venturi tubes.

**Tables – 2. Images – 5. Bibliography – 21 titles**

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**XeCl-excilamp with glow discharge excitation**

[*XeCl-eksilampa s vozbuzhdeniem tleiushchim razriadom*]

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**Abstract.** The object of study is a XeCl-excilamp with excitation by a glow discharge. The relevance of the work is due to the need to improve the spectral-emission and energy characteristics of excimer lamps and methods for their excitation. The aim of the study is to obtain conditions for the effective use of a direct current glow discharge to excite a working mixture in an XeCl-excilamp. The introduction provides a brief review of the literature, describing the basics and advantages of gas-discharge excitation of radiation sources, including excimer lamps with excitation by a dc glow discharge. Their advantages and disadvantages are given. The place of a direct current glow discharge for excimer lamps is considered and justified. The goals and features of the work are formulated. The main part describes the design of an excimer lamp with excitation by a dc glow discharge, a frequency-regulated high voltage source, and the results of its experimental modeling. The characteristic features of the combustion of a normal and anomalous direct current glow discharge in neon were revealed for conical and hemispherical electrodes with a blind hole along the axis. It is shown that when using cone-shaped electrodes at high discharge currents, the light output is higher than for hemispherical electrodes with a blind hole along the axis. It was shown that the low-current stage of the glow discharge is characterized by high visual radial uniformity and high intensity of ultraviolet radiation, while the high-current stage of the discharge is characterized by the contraction of the discharge column to the axis of the quartz tube. The value of the ultraviolet radiation efficiency of the XeCl-excilamp with excitation by a low-current direct current glow discharge of ~25 % was obtained at a specific radiation power of the order of ~0.1 W/cm<sup>3</sup>, which makes excitation of excilamps with a glow discharge attractive for further study and practical application. Necessary conclusions were made.

**Keywords:** excimer lamp, excimer molecule, exciplex molecule, glow discharge, discharge electrodes, gas-discharge plasma, current-voltage characteristic.

**Images – 10. Bibliography – 18 titles**

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### Features of tensile tests of composite reinforcement

[*Osobennosti ispytaniy na rastiazhenie kompozitnoi armatury*]

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**Abstract.** In the introduction, the state of the issue is analyzed and the relevance of the research topic is shown. The aim of the work is to create a methodology for calculating estimates and recommendations for ensuring the equal strength of the structural elements of composite reinforcement during testing of mechanical properties for tensile. Settlement schemes are compiled and a comparative structural and mechanical analysis of the bearing capacity of composite reinforcement is performed according to the criteria of strength at break of the rod, as well as the shear strength of its polymer shell. The main contribution during the tests is made by the strength of the polymer shell in special couplings for gripping the samples, as well as the alignment of the samples and couplings during the tests. The results of comparative tensile tests for coaxial and non-coaxial samples are presented and analyzed, which made it possible to establish that the contribution of the bending moment when creating a stress state is comparable to the contribution from tension and can lead to a noticeable distortion of the experimental results. Recommendations are given on calculating the minimum required coupling length and on ensuring alignment of samples and couplings. In conclusion, conclusions on the work are formulated and it is noted that the results can be used by manufacturers and consumers of building composite reinforcement, as well as in the educational process, in preparing engineering personnel for the construction profile.

**Keywords:** fiberglass reinforcement, composite reinforcement, tests, coupling tensile strength.

**Tables – 3. Images – 6. Bibliography – 13 titles**



**Creation of elastic concrete based on silicone additive**

[*Sozdanie elastichnogo betona na osnove silikonovoi dobavki*]

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**Abstract.** The article considers the results of the carried out primary study on the creation of innovative composite material “elastic concrete” by introducing into the classical concrete mixture an additive based on construction silicone materials. The main task of the development was to create a new concrete composition with improved operational properties and capable of withstanding significant elastic deformations without destroying its structure. The purpose of the study was to study the effect of additives created on the basis of a construction silicone sealant with different degree of concentration on the physical and mechanical properties of concrete with the possibility of obtaining a new composite material having properties of increased elasticity. Scientific novelty and relevance of the topic of development of “elastic concrete” corresponds to modern requirements applied to construction materials used in the construction of structures operated under special conditions – seismic dangerous zones subjected to various kinds of impact and dynamic loads, weather conditions, effects of temperature and humidity difference. The field of application of this type of construction material in the Republic of Belarus can be, for example, joints of floors and bridges, structures of high-rise buildings, and other responsible structures. The introduction contains a brief description of the object of the study, an overview of the world developments and application of “elastic concrete.” In the main part, the issues justifying the use of design components and testing methods are considered, the results of the study of the change in the properties of concrete products when the silicone additive is included in them in various concentrations are presented. Studies have shown that silicone materials in additives in certain proportions can improve the deformation properties of concrete. In conclusion, the main results of the research are formulated.

**Keywords:** elastic concrete, plasticizing additives, building silicone sealant, elasticity, elastic deformations, strength.

**Tables – 3. Images – 1. Bibliography – 12 titles**