MECHANICS

APPLICATION OF NUMERICAL SIMULATION METHODS FOR REDUCTION OF AIRCRAFTS ICE PROTECTION SYSTEMS ENERGY CONSUMPTION

Alekseyenko Sergey, PhD, Associate Professor, Department of Mechatronics, Oles Honchar Dnipro National University, Ukraine, e-mail: alexeyenko_sv@ukr.net, ORCID: http://orcid.org/0000-0003-0320-989X

Yushkevich Oleg, PhD, Associate Professor, Department of Mechatronics, Oles Honchar Dnipro National University, Ukraine, e-mail: ReilTO@i.ua, ORCID: http://orcid.org/0000-0002-7199-8424

The object of research is the processes of hydrodynamic and heat and mass transfer occurring during the icing of aircraft during flight in adverse meteorological conditions, as well as the system of protection against icing. One of the problematic places in the development of anti-icing systems is minimization of their energy consumption while ensuring flight safety.

In the course of the study, the developed software and methodological software was used to simulate the processes of icing of aircraft. An approach based on the Navier-Stokes equations and the model of interpenetrating media was used to describe the external airborne flow, as well as the loss of moisture on the streamlined surface. The numerical simulation of the ice buildup process was performed using the method of surface control volumes based on the equations of continuity, conservation of momentum and energy.

Research results are presented on the example of the viscous compressible air-droplet flow around the NACA 0012 wing profile. More accurate distributions of the main flow parameters at the boundary layer boundary, convective heat exchange along the streamlined surface, as well as the basic quantities included in the equations of mass and heat balances are obtained. This is due to the fact that the proposed approach takes into account the viscosity and compressibility of the flow, and also has a number of features when describing the external flow. In particular, a modified Spalart-Allmaras turbulence model is used, taking into account the wall roughness. Thanks to this, it is possible to determine the coefficient of convective heat exchange by the temperature field found. Compared with the well-known traditional methods that use integral ratios, this approach allows to take into account the history of the flow, can be applied in the case of sufficiently high speeds and complex ice forms, in problems in the three-dimensional formulation. Also, this approach makes it possible to determine the aerodynamic characteristics of profiles with ice buildups, taking into account the surface roughness.

The results of the work can be used to optimize the operation of anti-icing systems and determine ways to reduce energy costs when operating such systems.

Keywords: icing of aerodynamic surfaces, anti-icing systems, mathematical modeling of the ice buildup process.

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DETERMINATION OF THE SIZE OF THE SEAL ZONE AND THE SOIL PRESSURE ON UNDERGROUND COMMUNICATIONS IN THE PROCESS OF SOIL DEFORMATION BY THE WEDGE-SHAPED TIP

Posmituha Alexander, Senior Lecturer, Department of Applied Mechanics and Materials Science, Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Dnipro,

Ukraine, e-mail: AleksandrP@3g.ua, ORCID: http://orcid.org/0000-0002-9701-3873

Kravets Svyatoslav, *Doctor of Technical Sciences, Professor, Department of Building, Road, Melioration, Agricultural Machinery and Equipment, National University of Water and Environmental Engineering, Rivne, Ukraine, ORCID: http://orcid.org/0000-0003-4063-1942, e-mail: s.v.kravets@nuwm.edu.ua*

Suponyev Vladimir, *PhD, Associate Professor, Department of Build and Travelling Machines, Kharkiv National Automobile and Road University, Ukraine, ORCID: http://orcid.org/0000-0001-7404-6691, e-mail: v-suponev@ukr.net*

Kulazhenko Yevhenii, *Assistant, Department of Bridges and Tunnels, Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Dnipro, Ukraine, ORCID: http://orcid.org/0000-0002-4529-7384, e-mail: Jaksson7777@gmail.com*

The object of research is a working element with a wedge-shaped tip for static perforation of the soil with the laying of several cases for underground utilities. One of the problems that require research is the laying, location and proximity of various types of underground utilities, laid trenchless way. The study of the zone of influence of working bodies on the ground and communication will give the opportunity to more efficiently design the use of underground space, to reduce the risks of damage to or destruction of communications and reduce the cost of the work. Studies are based on the law of conservation of mass before and after compaction of the soil with a wedge-shaped tip and on the basic theories of soil mechanics. This allows to determine the pressure of the soil on the working element and on the communication, located nearby. The result obtained in the work shows that the pressure value is not the same in different directions of the wedge working element. It is also proved that the number of cases, which are simultaneously laid, have little effect on the zone of elastic-plastic deformation of the soil. These effects make this form of hole indispensable when it is necessary to simultaneously lay several, more than 3, cases, compared to the traditional conical-cylindrical tip. To determine the soil pressure on underground utilities are used only the size of the working elements, and data that are easy to determine – the type and density of soil, humidity, porosity and other standardized characteristics. The use of this method has a significant advantage over other methods, which are based on empirical relationships that are either difficult to determine or their reliability is questionable. Due to the reduction of the cross-sectional area of the deformable soil, the wedge working body is indispensable for stretching the group of cases.

Keywords: trenchless technology, static perforation of soil, sealing zone, soil pressure, engineering communications.

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MATERIALS SCIENCE

K₂GeF₆ COMPOUND CRYSTALLINE STRUCTURE ANALYSIS

page 17—22

Zavodyannyy Viktor, *PhD, Associate Professor, Department of Physics and General Engineering Disciplines, State Higher Educational Institution «Kherson State Agrarian University», Ukraine, e-mail: zavodyannyy@gmail.com, ORCID: http://orcid.org/0000-0002-8224-8215*

The object of research is the crystal structure of the polymorphic modification of the K_2GeF_6 compound. One of the problem areas is the existence of a large number of diffraction spectra obtained with the Bragg-Bertrand survey geometry in the PDF-2 database for 2004. This paper proposes a structural model for the diffraction spectrum of the compound numbered 00-037-1154.

The study used the PDF-2 database for 2004. As well as the program HiphScorePlus 3.0, which allows to refine the microstructural parameters of the structural model using the Rietveld method.

As a result, it was obtained that this diffraction spectrum of the studied compound can correspond to the following structural model:

– orthorhombic syngonies, Imma symmetry space group, lattice $a = 8.3327$ A°, $b = 5.891212$ A°, $c = 5.908473$ A°;

– the microstructural parameters of Ge 16j $x/a = 0.172086$, $y/b = 0.353968$, $z/c = 0.291034$;

– the fill factor of positions 0.25 K 16j $x/a = 0.316837$, $y/b = 0.636701$, $z/c = 0.134786$;

– fill factor of 0.5 F1 16j $x/a = -0.087258$, $y/b = 0.119218$, $z/c = 0.783618$;

– fill factor of the positions 0.5 F2 16j $x/a = 0.406830$, $y/b = -0.603655$, $z/c = 0.376365$;

– fill factor of positions 0.5 F3 8f $x/a = 0.581125$, $y/b = 0$, $z/c = 0$;

– fill factor of positions 1.0;

– disagreement factor $R = 8.65453$ %.

Analyzing the obtained results, it is possible to assume that in addition to two known polymorphic modifications of the compound, namely, trigonal and hexagonal syngonies, there is a new polymorphic modification and has its own structural type. The correct system of points of 16j for atoms of germanium, potassium and fluorine is not completely filled.

It is shown that the crystal structure of the compound is associated with its optical properties. In particular, crystals of trigonal and hexagonal systems have an absorption spectrum in the infrared region. The influence of the crystal structure on the scattering spectra of this compound has also been observed. There is also a splitting of radiation lines, which is closely related to the structure of the crystal lattice. Therefore, the study of this polymorphic modification of the K_2GeF_6 compound provides an opportunity to consider and study its optical properties in a new way, thanks to which it can be used as a phosphor for the commercial production of LEDs.

Keywords: X-ray structural analysis, Bragg-Bertrand survey geometry, Rietveld method, crystal structure, K_2GeF_6 composition.

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ELECTRICAL ENGINEERING AND INDUSTRIAL ELECTRONICS

STUDY OF THE INDUCTION MOTOR ELECTRIC DRIVE EFFICIENCY IN TRANSIENTS DURING THEIR ACCELERATION

Ostroverkhov Mykola, Doctor of Technical Sciences, Professor, Head of the Department of Theoretical Electrical Engineering, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Ukraine, e-mail: n.ostroverkhov@hotmail.com, ORCID: http://orcid.org/0000-0002-7322-8052

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Reutskyi Mykola, PhD, Associate Professor, Department of Electrical Mechanics, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Ukraine, e-mail: rmo318@i.ua, ORCID: http://orcid.org/0000-0003-1870-2222

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Trinchuk Danylo, Postgraduate Student, Department of Theoretical Electrical Engineering, National Technical University of Ukraine «Igor Sikorsky Kyiv Polytechnic Institute», Ukraine, e-mail: d.trinchuk@gmail.com, ORCID: http://orcid.org/0000-0001-6022-9323

The electric drive with a squirrel-caged induction motor working in frequent start-stop modes is the object of this study. These drives have wide applications nowadays, such as in electric vehicles and hybrid electric vehicles, so improvement of their efficiency during the transients is an important task today.

The one of the problems of such drives lays in the high energy consumption during the transients, especially if we talk about the acceleration of the motor. Due to the high starting currents large amount of consumed energy is dispersed as heat on the motor windings. The experimental studies carried out in this work have proved the necessity of limitations of these currents. However, such a decision will lead to the increase of the motor acceleration period which means that the starting currents, even having lesser magnitude, will last longer. This consequence will, therefore, also cause higher energy losses. So, there should be a point of the optimum – the acceleration period, during which the electric drive consumes the least possible energy.

In order to determine the optimal acceleration period, the computer model of the electric drive with a squirrel-caged induction motor, controlled by a smooth start device, was developed in this paper. The smooth start device provides the possibility of evenly increasing of the voltage from zero to the rated value. The research has proven the existence of the optimal voltage increasing period, during which the motor acceleration heat losses are minimal. This optimal point depends only on the motor-drive system parameters and remains consistent for any applied load. The research results provide the possibility of improving the efficiency of the electric drives working in frequent start-stop modes due to a slight increasing of the motor acceleration period that leads to the reduction of the starting currents.

Keywords: induction motor, smooth start device, efficiency during accelerations.

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PRACTICAL APPLICATION OF MATHEMATICAL MODELS OF ELECTRO-THERMO-MECHANICAL PROCESSES IN INDUSTRIAL INDUCTION FURNACES WITH THE AIM OF INCREASING THEIR ENERGY EFFICIENCY

page 28–33

Pachkolin Yurii, *PhD, Associate Professor, Department of Power Supply of Industrial Enterprises, Zaporozhye National Technical University, Ukraine, e-mail: pachkolin@ukr.net, ORCID: http://orcid.org/0000-0003-0216-8184*

Bondarenko Alexander, *Postgraduate Student, Department of Electrical Apparatus, Zaporozhye National Technical University, Ukraine, e-mail: bondarenko.aleksander@gmail.com, ORCID: http://orcid.org/0000-0002-1369-0034*

Levchenko Serhii, *PhD, Associate Professor, Department of Electrical Engineering and Energy Efficiency, Zaporozhye State Engineering Academy, Ukraine, e-mail: vysnovok@gmail.com, ORCID: http://orcid.org/0000-0001-6477-2825*

The object of research is an industrial induction steel-melting furnace. One of the most problematic places in induction steel-melting furnaces is low energy efficiency due to their constructive imperfections and the existing technological process of thermal work, which leads to excessive energy consumption.

In the course of the study, mathematical modeling of the influence of the electromagnetic field on the elements of an induction furnace was used. Experiments were also carried out to verify the action of the electromagnetic field on the trajectory and speed of movement of the molten metal both in laboratory conditions and in an induction furnace. To study the movement of the molten metal, a special thermal float was manufactured. The float consists of a ceramic heat-resistant sleeve, into which a tungsten rod is inserted. For greater accuracy of the experiment, the float weight is equal to the weight of the melt of the same volume. Thanks to the experiments conducted in the laboratory and on the furnace, an algorithm was developed for the operating modes of the electric inductor. The analysis of the inductor operation modes at different frequencies is carried out. The influence of the frequency of the current supplying the inductor to the penetration depth of the electromagnetic field is revealed. With decreasing current frequency ($f < 50$ Hz), the penetration depth increases and vice versa, with increasing ($f > 50$ Hz) it decreases. It is also confirmed that the maximum effect of the electromagnetic field on the melt is concentrated inside (along the height) of the melt.

The main issues of practical application of the mathematical model of electro-thermo-mechanical processes arising in industrial induction furnaces during heating and melting of various metals and their alloys, which are widely used in mechanical engineering, are considered. The system of equations in the form of boundary-value problems of electrodynamics for a quasi-stationary magnetic field, non-stationary heat conduction and non-isothermal thermoplasticity is used. The practical application of the proposed methods of using the capabilities of mathematical modeling of electrometallurgical processes is the basis for the creation of modern computer programs with the aim of improving energy efficiency by significantly reducing unnecessary, unreasonable energy losses.

Keywords: induction steel-melting furnace, mathematical modeling of electro-thermo-mechanical processes, boundary problems of electrodynamics, induction heating.

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TECHNOLOGY AND SYSTEM OF POWER SUPPLY

COMPARATIVE ANALYSIS OF THE EFFICIENCY OF GAS BOILERS BY EXPRESS METHOD OF MULTI-CRITERIA ASSESSMENT

Demchenko Volodymyr, PhD, Senior Researcher, Head of the Department of Processes and Technologies of Heat Supply, Institute of Engineering Thermophysics of National Academy of Sciences of Ukraine, Kyiv, Ukraine, e-mail: vptt@i.ua, ORCID: http://orcid.org/0000-0002-4211-356X

Trubachev Andrii, PhD, Senior Researcher, Department of Processes and Technologies of Heat Supply, Institute of Engineering Thermophysics of National Academy of Sciences of Ukraine, Kyiv, Ukraine, e-mail: astrubachev@gmail.com, ORCID: http://orcid.org/0000-0002-2903-2810

Hron Serhii, Engineer, Institute of Engineering Thermophysics of National Academy of Sciences of Ukraine, Kyiv, Ukraine, e-mail: sergey.gron2204@gmail.com, ORCID: http://orcid.org/0000-0002-9885-069X

The object of the research is a method of fast analysis of multi-criteria evaluation on the example of comparing the efficiency of domestic gas WHGA-type boilers. Currently, the Ukrainian market offers a large number of gas boilers of Ukrainian and foreign manufacturing plants, which has minor differences. This is primarily due to the simplicity of the constructive solution of gas boilers of this model and using the same Italian burner devices and automation units for them.

Comparing the efficiency of this type of product is a big problem. Existing methods of calculating efficiency indicators and existing regulatory documents do not always give a correct value of product quality. Therefore this paper proposes a new method of express analysis of efficiency comparison, which allows in a short time to make a correct comparison of the efficiency of boiler equipment without using a large number of calculations that require a lot of time. This problem is solved by choosing three anchor efficiency criteria, namely, energy, environmental and economic, with the subsequent determination of the confidence intervals of each of the indicators and the construction of a three-criterion diagram on their basis. This method allows to visually see the disadvantages and advantages of each of the boilers, plan measures for their modernization and determine their rating.

In the course of the research, materials from a technical report of warm-heat tests of seven gas boilers using the standard technique were used. The analysis of the results was performed using the sum method followed by ranking of affects and subsequent verification of the proposed quick method of comparison of effectiveness. The obtained qualitative result allows to conclude that the proposed express method in more detail and correctly than other known methods of analysis determines the rating position of each boiler. This allows a potential investor to draw the right conclusion when replacing and purchasing new boiler equipment. Using the method of express analysis allows manufacturers of boiler equipment to conduct a real assessment of product quality and identify ways to overcome its shortcomings.

Keywords: gas boiler, energy equipment efficiency, system analysis, weighting factor.

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STUDYING OF THE POWER MODES IN THE TRACTION LINE FOR ENSURING THE HIGH-SPEED TRAFFIC

Hubskyi Petro, Postgraduate Student, Department of Intelligent Power Supply Systems, Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Dnipro, Ukraine,

e-mail: peter.gybskiy@gmail.com, ORCID: http://orcid.org/0000-0002-0216-7256

Kuznetsov Valeriy, Doctor of Technical Sciences, Professor, Department of Intelligent Power Supply Systems, Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Dnipro, Ukraine, e-mail: vkuz@i.ua, ORCID: http://orcid.org/0000-0003-4165-1056

Drubetskyi Anton, PhD, Assistant, Department of Electric Rolling Stock, Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Dnipro, Ukraine, e-mail: drubetskiy.ae@gmail.com, ORCID: http://orcid.org/0000-0001-5691-0925

Afanasov Andrii, Doctor of Technical Sciences, Professor, Department of Electric Rolling Stock, Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan, Dnipro, Ukraine, e-mail: afanasof@ukr.net, ORCID: http://orcid.org/0000-0003-4609-2361

Pulin Mykola, Deputy Chief of Power Supply, Regional Branch «Lviv Railway» of PJSC «Ukrzaliznytsia», Ukraine, e-mail: ee@railway.lviv.ua, ORCID: http://orcid.org/0000-0003-0929-671X

The object of research is the power regimes in traction power systems for both centralized and distributed power when introducing high-speed traffic. The introduction of high-speed traffic on electrified railways of Ukraine has begun a number of restrictions in the applied system of traction power supply of centralized power supply. These include not only the impossibility of providing the necessary voltage level of 2.9 kV, but also the low efficiency of the aggregate power of traction substations. In this case, the applied traction power system does not allow to provide the necessary level of specific power in the traction network. Applicable technical means and measures to strengthen the traction network do not allow, in most cases, to provide regulatory requirements for the organization of high-speed traffic.

An analysis of modern research shows that overcoming these disadvantages is possible due to the application of a distributed power supply system to the traction network. To date, sufficient options have been developed for constructing such systems, but in this paper, as an alternative, a system was considered with the distribution of the aggregate power available in the system of centralized power in the inter-substation zone. At the same time it was reasonable to reduce the power of the traction substation to the level of 10 MW.

During the study of power regimes in comparable traction power systems, the results of experimental studies and simulation modeling of the operating modes of the comparable systems were used. Calculations were taken into account not only the specifics of the traction load, but also its impact on the load capacity of the contact suspension. As a result of this approach, it has been shown that the distributed traction power system allows to fulfill the regulatory requirements for providing high-speed traffic. With its application, the consumption of electric energy for traction of trains is reduced by 40 %, the specific power of traction network increases by 90 %, and the load factor of traction substations – by 60 %.

The proposed innovative approach to providing the necessary power mode in the traction line for the organization of high-speed traffic allows to preserve the existing infrastructure on existing electrified section of direct current. This approach allows the application of various types of electric rolling stock and provides the required capacity of the railways.

Keywords: traction power system, centralized power supply, distributed power, specific power, voltage level, high-speed motion.

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DEVELOPMENT OF AN APPROACH TO AUTOMATION OF GAS TRANSMISSION SYSTEM MANAGEMENT

page 52–60

Chekurin Vasyl, Doctor of Physics and Mathematics, Professor, Head of the Department of Mathematical Problems of Mechanics of Heterogeneous Solids, Ya. S. Pidstryhach Institute for Applied Problems of Mechanics and Mathematics of NAS of Ukraine, Lviv, Ukraine, e-mail: v.chekurin@gmail.com, ORCID: http://orcid.org/0000-0003-4973-3670

Ponomaryov Yuriy, PhD, Associate Professor, Deputy Director for Science, Research and Design Institute of Gas Transportation of JSC «Ukrtransgaz», Kharkiv, Ukraine, e-mail: ponomarev-yv@utg.ua, ORCID: http://orcid.org/0000-0002-5677-3657

Prytula Myroslav, PhD, Department of Designing Systems of Optimal Scheduling and Forecasting Operating Modes of GTS, Research and Design Institute of Gas Transportation of JSC «Ukrtransgaz», Kharkiv, Ukraine, e-mail: myroslav.prytula@gmail.com, ORCID: http://orcid.org/0000-0001-9259-4114

Khymko Olga, PhD, Associate Professor, Department of Automation and Computer-Integrated Technologies, Lviv Polytechnic National University, Ukraine, e-mail: olgakhymko@ukr.net, ORCID: http://orcid.org/0000-0003-2641-8133

The object of research is the management system of the gas transmission system (GTS) of Ukraine. The analysis shows that the GTS effectiveness is hampered by the information heterogeneity of the available automation means and the lack of automated data exchange on the vertical «process control – strategic management».

The study applied the methodology proposed by the ANSI/ISA-95 standard, the reference model of the functional hierarchy of management of manufacturing enterprises.

As a result of the research, the functions of the processes acting at the operational level, are determined. An approach to the phased automation of the management of GTS is developed. It provides for the preservation and development of existing means of automation of technological processes and existing systems for planning, optimization and management by gas pipelines and underground gas storage facilities. According to the proposed approach, an operational management system will be created on the basis of existing computerized systems as an MES system that will meet the requirements of this standard.

The implementation of the proposed approach can be considered as a combination of two processes, each of which is implemented in three stages, performed iteratively. The first process: creation of operational management systems as MES systems, introduction of automatic monitoring of parameters of physical and technological processes, and the formation of a subsystem of information system responsible for ensuring operational management and control of technological processes. The second process includes: formation of a subsystem of information system responsible for ensuring of business processes, introduction of an automated system for management on the corporate level and the introduction of automatic monitoring of business processes.

The interaction of these two processes can occur only in their final phases of final formation of the information system. Therefore, they can be implemented in parallel, which will ensure a reduction in the duration of the GTS reconstruction on the proposed approach. And this, in turn, will lead to a reduction in the period of recoupment of expenses for the introduction of the system. Implementation of the proposed approach as a whole will improve the controllability and efficiency of the GTS operation and create conditions for introducing of modern management models.

Keywords: gas transmission systems, management automation, ISA-95 standard, MES systems.

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ALTERNATIVE AND RENEWABLE ENERGY SOURCES

INFLUENCE OF PRE-SOWING UV-RADIATION ON THE ENERGY OF GERMINATION CAPACITY AND GERMINATION ABILITY OF RAPESEED

Semenov Anatoly, *PhD, Associate Professor, Department of Commodity Studies, Biotechnology, Expertise and Customs, Poltava University of Economics and Trade, Ukraine, e-mail: asemen2015@gmail.com, ORCID: http://orcid.org/0000-0003-3184-6925*

Kozhushko Gregory, *Doctor of Technical Sciences, Professor, Department of Commodity Studies, Biotechnology, Expertise and Customs, Poltava University of Economics and Trade, Ukraine, ORCID: http://orcid.org/0000-0002-7306-4529*

Sakhno Tamara, *Doctor of Chemical Sciences, Professor, Department of Commodity Studies, Biotechnology, Expertise and Customs, Poltava University of Economics and Trade, Ukraine, e-mail: sakhno2001@gmail.com, ORCID: http://orcid.org/0000-0001-7049-4657*

The object of research is the rapeseed, which is the first among oilseeds by the volume of sowing. One of the most problematic places of the agricultural complex is an increase in the quantity and quality of the seed material. To solve this problem, scientists and agricultural specialists use various methods, preferring optical radiation – pre-sowing UV-seed treatment. Selection of treatment regimes requires detailed studies and a differentiated approach for each crop separately.

In the work pre-sowing influence of ultraviolet UV-irradiation of rapeseeds on biological processes (germination energy, germination and growth) is investigated. 20 W low-pressure ultraviolet lamps of the type ZW20D15W (China) emitting in the C region are used. The radiation dose is measured according to standard methods using a Tenzor-31 radiometer (Ukraine).

Samples of rapeseeds, in addition to control, are irradiated with ultraviolet radiation in the C region with doses of $10\,J/m^2$, $20\,J/m^2$, $50\,J/m^2$, $80\,J/m^2$, $100\,J/m^2$, $120\,J/m^2$ and $200\,J/m^2$. Irradiated and control samples of seeds are germinated in Petri dishes at an air temperature of $24\pm2\,°C$. The number of seedlings is counted after 3 days – the germination energy, and after 7 days – germination ability.

Due to the use of UV irradiation at doses of $80–120\,J/m^2$, the following results are obtained in comparison with the control sample: the germination energy of rapeseeds is increased by 20–26 %; germination ability increases by 16 %. At the same time, the average biomass of plants from irradiated seeds increases by 18.3 % in comparison with the control samples for 10 days of growth.

In field studies, the germination of rapeseeds after irradiation with a UV-C dose of $120\,J/m^2$ compared to the control sample increased by 16 % and becomes 89 %.

Keywords: UV irradiation, irradiation dose, pre-sowing seed treatment, germination energy, rapeseed germination.

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