

# CONTENTS

## MECHANICAL

- F. N. Pritykin.** Study of kinematic parameters of android robot in automated synthesis of motions on velocity vector 5
- V. A. Korotkii.** Constructive algorithms for forming compound cubic Bezier curves in space and on plane 10
- V. Yu. Yurkov.** Isoline families in the space with rectilinear distances 17
- T. M. Myasoedova, K. L. Panchuk, E. V. Lyubchinov.** Inverse problem of cyclographic modeling of spatial curve 21
- A. H. Shamutdinov, I. Yu. Lesnyak.** Method for determining reactions in hinges of mechanism of original manipulator 28
- A. M. Badamshin, A. O. Leptyuk.** Study of morphology, chemical composition and corrosion resistance of «TiC – NiTi» hard alloy modified by powerful ion beam 33
- R. T. Islamov, F. F. Khabibullin, M. R. Faizov.** Study of kinematics of spatial 5R mechanism with 4 cyclic motion 38
- S. Yu. Lebedev.** Analysis of methods for calculating tooth interior fatigue fracture 43
- S. V. Pashukevich.** Development of grease resistant to water washout 48

## ENERGY AND ELECTRICAL ENGINEERING

- A. A. Kuznetsov, S. S. Gorobei.** Reduction of electric energy consumption for heating passenger railway carriages 54
- R. N. Khamitov, R. V. Kuzmin, A. S. Meshkov, V. I. Susdorf, K. G. Pivovarov.** Generator of microelectric power plants for low-potential watercourses 59
- V. A. Shpenst, E. A. Orel.** Evaluating possibility of creating modular DC/DC power supplies with configurable structure 64
- S. N. Kladiev, A. D. Umurzakova, N. D. Sarbasova, K. V. Khatsevskiy.** Simulation modeling of the tracking electric drive of sorting conveyor 72
- Yu. N. Kondrashova, A. V. Shalimov, A. M. Markina, A. M. Tretiakov.** Reliability assessment of electrical equipment of metallurgical plant for separate sections in relation to types of technological production 77
- P. M. Korusenko, S. N. Nesov, K. E. Ivlev.** Morphology, structure, and electrochemical properties of the MnO<sub>x</sub>@CNTs composite: a study of SEM, EDX, XPS, and CVA methods 86

## ELECTRONICS, PHOTONICS, INSTRUMENT ENGINEERING AND COMMUNICATION

- S. V. Biryukov, L. V. Tyukina, A. V. Tyukin.** Measuring circuits of two double electro-induction spherical sensors of electric field strength of closed type constructively united into a single whole 93
- S. V. Biryukov, L. V. Tyukina, A. V. Tyukin.** Calibration of double electroinduction spherical electric field strength sensor in a homogeneous field 102
- E. V. Leun.** On the issue of achieving subpicometric resolution by acousto-optic two-channel laser displacement interferometer with two different frequency photodetectors 110
- A. S. Gorbunov, M. V. Elfimova, Y. N. Bezborodov.** Study of changes in color characteristics of steel under thermal exposure 119
- O. I. Gordeev, V. A. Zakharenko.** The hardware and software complex for electromechanical equipment diagnostic 125

## SUMMARY. KEYWORDS

### MECHANICAL

**F. N. Pritykin**

**Study of kinematic parameters of android robot in automated synthesis of motions on velocity vector**

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

The modernization of the method of synthesis of motions of manipulators by speed vector allows to exclude motions the emergence of dead ends in the process of computer simulation. The developed algorithm is based on the use of a database characterising the values of kinematic parameters that specify the permissible instantaneous states of the mechanism of the manipulator at different positions. The graphical representation of the hypersurface of the reflective relationship of the specified parameters from the values of the generalized coordinates is made. On the basis of this, a method for determining the above kinematic parameters is proposed, which makes it possible to reduce the time for calculating intermediate configurations on a given trajectory of the output link and to eliminate the occurrence of deadlock situations.

Keywords: mechanisms of manipulators, instantaneous states of mechanisms, vector of generalized speeds, computer simulation of robot motions, robotics, output link.

**V. A. Korotkii**

**Constructive algorithms for forming compound cubic Bezier curves in space and on plane**

**South Ural State University (National Research University), Chelyabinsk, Russia**

The article considers two graph-analytical algorithms. The first algorithm makes it possible to form a spatial curve passing through given nodal points with direction vectors specified at these points. The second algorithm allows you to generate a flat compound curve passing through the given nodal points with direction vectors and curvature radii specified at these points. The constructed curves are formed by cubic Bezier segments. Direction vectors are treated as a control for the shape of the curve being constructed. At the nodal points, second-order geometric smoothness is ensured, due to the continuity of the slope and curvature. A distinctive feature of the proposed algorithms is the significant use of constructive means of computer graphics.

Keywords: cubic segment, direction vector, curvature, torsion, geometric smoothness.

**V. Yu. Yurkov**

**Isoline families in the space with rectilinear distances**

**Omsk state technical university, Omsk, Russia**

The paper is devoted to planar linear sets generated by linear conditions which are realized for rectangular or Manhattan metrics. The aim of this paper is to give an approach to researching the properties of linear conditions defined on Manhattan plane. Linear conditions are written as a finite sum of products Manhattan distances and real numerical factors. The paper presents a constructive method to solve the next general geometric problem. Let finite sets of linear figures (segments of line, polygons) are given on Manhattan plane at general positions. Find a planar set corresponding to given linear condition based on the given sets. The set of broken lines corresponding to given conditions generates a family of isolines for given sets. Constructive algorithm to build the family is suggested. The algorithm is based on the rectangular Hanan lattice and calculation numerical values in each cell. Some theorems applied to these cases are formulated in the paper.

Keywords: rectangular metrics, distance, linear conditions, Hanan lattice, isoline families, polygons.

**T. M. Myasoedova, K. L. Panchuk,**

**E. V. Lyubchinov**

**Inverse problem of cyclographic modeling of spatial curve**

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

The objective of the present study is to justify the possibility of constructive and analytic solution to the inverse problem of cyclographic modeling of a curve of space  $R^3$  and development of a respective algorithm. The orthogonal projection and the two components of the cyclographic projection of a spatial curve form a triad of elements in plane  $z=0$ . These elements are the result of the direct problem solution and constitute the basis for the inverse problem solution. The direct problem consists in construction in plane  $z=0$  of a cyclographic projection (a model) of a given spatial curve, while the inverse problem consists in determination of a spatial curve given its cyclographic projection. Insufficient knowledge on the inverse problem as well as its relevance in practical applications, e.g. in cutting tool trajectory calculation for pocket machining of mechanical engineering products on NC units, make urgent the definition and the solution of the inverse problem. In the present paper a simple convex closed curve is considered as the

given cyclographic projection. It is proven that there exists a unique spatial curve, for which the given curve constitutes a cyclographic projection. The algorithm for the inverse problem solution is demonstrated on examples.

Keywords: cyclographic mapping, medial axis, medial transformation axis, inverse task,  $\alpha$ -shell, vertex points of the curve.

**A. H. Shamutdinov<sup>1</sup>,  
I. Yu. Lesnyak<sup>2</sup>**

**Method for determining reactions in hinges of mechanism of original manipulator**

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

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

This article discusses the development of a method for determining reactions in the hinges of a manipulator, based on the classical principle of release from bonds in the example of its main part. A model of a manipulator has been compiled, in which, in the general case, a force  $F$  of arbitrary orientation acts on the working platform. The design scheme of the manipulator is compiled and a complete calculation is made under the action of the horizontal component force  $F_x$ . By analogy, the reactions from the action of the horizontal  $F_y$  and vertical  $F_z$  components of forces are determined and general dependencies are derived. Knowledge of the numerical values of the found reactions in the hinges of the manipulator will allow, according to known hypotheses, to calculate this manipulator for strength and rigidity.

Keywords: original manipulator, working table, inclined platform, turntable, rotary table, hydraulic cylinder, reactions in hinges.

**A. M. Badamshin, A. O. Leptyuk**  
**Study of morphology, chemical composition and corrosion resistance of «TiC–NiTi» hard alloy modified by powerful ion beam**

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

The article presents the results of a study of the effect of ion–beam treatment with a high–power ion beam (HPIB) on the change in topography, morphology, chemical composition and corrosion resistance of the surface layers of a tungsten–free hard alloy of the «TiC–NiTi» system. The samples are characterized by scanning electron microscopy, energy dispersive X–ray analysis, scanning probe microscopy, and metallographic analysis. It is revealed that due to the impact of HPIB, the surface layer of the sample undergoes melting with the formation of extended microcracks. At the same time, a decrease in the oxygen concentration from 24,6 to 13,7 at. % is recorded in the surface layer of the sample, and at some points on the sample it is completely absent. This result indicates the dissociation of titanium oxide under the influence of temperatures arising during HPIB irradiation. It is most likely that it is the thermal dissociation of titanium oxide and melting of the sample surface that

are the main reasons for the increase in the corrosion resistance of the «TiC–NiTi» system alloy.

Keywords: tungsten–free hard alloys, powerful ion beam, surface morphology, corrosion resistance, scanning and atomic force microscopy.

**R. T. Islamov, F. F. Khabibullin,  
M. R. Faizov**  
**Study of kinematics of spatial 5R mechanism with 4 cyclic motion**

**Kazan National Research Technical University named after A. N. Tupolev – KAI, Kazan, Russia**

This article presents Bennett's five-bar spatial mechanism. For interest, we will define the kinematic parameters of the mechanism. The obtained parameters displayed on the graphs of the dependences of the rotation of the input link to the output. Additionally, for an accurate calculation, an additional ghostly angle of the mechanism is taken into account. Additional link ratios specified.

Keywords: five-link mechanism, Bennett, ghostly angle, two driving links, crank.

**S. Yu. Lebedev**  
**Analysis of methods for calculating tooth interior fatigue fracture**

**Industrial University of Tyumen, Tyumen, Russia**

The tooth interior fatigue fracture is an important criterion for the performance of a gear. The article analyzes the existing methods for determining the tooth interior fatigue fracture of cylindrical gears. Methods (Findley, V. I. Korotkina, E. I. Tesker and V. N. Syzrantsev) are validated on the basis of available experimental data. The results are presented in the form of graphs of changes in the safety factor for the depth of a case and a summary table of calculations and experimental results.

Keywords: tooth interior fatigue fracture, cylindrical gear, Pisarenko-Lebedev strength criterion, Findley criterion.

**S. V. Pashukevich**  
**Development of grease resistant to water washout**

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

In the work, laboratory tests are carried out to create a grease with the introduction of waterproof components into the composition with further analysis of samples of the resulting lubricant. A technique has also been developed to measure the washout of greases. During the tests, the values of the following technological properties of greases are obtained: dropping point, penetration at 25 °C with stirring, colloidal stability, welding load, washout, freezing point, tensile strength at 20 °C and at 80 °C. A comparative analysis of each of the considered indicators of five samples

of the developed lubricant and samples of already manufactured products are carried out.

Keywords: lubricants, greases, dropping point, colloidal stability, welding load, tensile strength, freezing point.

## ENERGY AND ELECTRICAL ENGINEERING

**A. A. Kuznetsov, S. S. Gorobei**  
**Reduction of electric energy consumption for heating passenger railway carriages**

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

The article provides an overview of circuit solutions and describes the elements of power supply system of a passenger car. A combined heating system for a passenger car is described. The results of experimental studies on saving electrical energy using voltage regulators are presented. The article proposes an algorithm for controlling electric heaters based on the use of semiconductor power regulators. Experimental studies using the proposed high-voltage regulators as part of passenger car heaters made it possible to reduce the cost of power supply for a passenger car from 3 % to 5 % during their operation.

Keywords: power supply, passenger railway carriage, heating, experiment, voltage regulator, saving electricity.

**R. N. Khamitov<sup>1</sup>, R. V. Kuzmin<sup>2</sup>, A. S. Meshkov<sup>2</sup>,  
V. I. Susdorf<sup>2</sup>, K. G. Pivovarov<sup>2</sup>**  
**Generator of microelectric power plants for low-potential watercourses**

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

<sup>2</sup>**Komsomolsk-on-Amur State University,  
Komsomolsk-on-Amur, Russia**

The development of autonomous power supply systems based on micro-hydroelectric power plants using the energy of small watercourses is associated with the fulfillment of a number of contradictory requirements. The source should be fairly simple and cheap. A promising direction in the construction of such sources that ensure the fulfillment of these requirements is the creation of electric energy generation systems based on a generator whose inductor is combined with a hydraulic turbine. The article is devoted to the issues of designing and ensuring high performance characteristics of such micro-hydroelectric power plants.

Keywords: magnetic field, induction in the air gap, generator with sectional inductor, hydraulic turbines, microelectric power plants.

**V. A. Shpenst, E. A. Orel**  
**Evaluating possibility of creating modular DC/DC power supplies with configurable structure**

**Saint Petersburg Mining University, Saint-Petersburg, Russia**

The paper deals with the problem of creating power supplies for autonomous electrical complexes. The

paper demonstrates that the lifetime and efficiency of their operation can be improved by using two fundamental principles: modular construction of the system and intellectual principles of its operation. The article proposes the idea of creating a configurable power supply with power range up to 10 kW, consisting of typical, mass-produced power modules forming together a structure  $M \times N$ , where it is possible to change their interconnections and perform current and voltage control of each module.

Keywords: autonomous electrotechnical complex, fault tolerance, efficiency, digital control.

**S. N. Kladiyev<sup>1</sup>, A. D. Umurzakova<sup>1</sup>,  
N. D. Sarbasova<sup>2</sup>, K. V. Khatsevskiy<sup>3</sup>**  
**Simulation modeling of the tracking electric drive of sorting conveyor**

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

<sup>2</sup>**Toraighyrov University, Pavlodar, Republic of Kazakhstan**

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

The aim of the study is to develop methods for forming a control channel for sorting roundwood based on an asynchronous three-phase motor with a phase rotor. In the study, a simulation modeling method is used to verify the operability of the developed implementation of the control channel, and to evaluate the errors in the functioning of the control system. Based on the results obtained, it can be concluded that the proposed method of forming a control channel for controlling discrete sorting devices can be used.

Keywords: wound-rotor induction motors, simulation model, control channel, roundwood sorting, sorting process automation, conveyor.

**Yu. N. Kondrashova, A. V. Shalimov,  
A. M. Markina, A. M. Tretiakov**  
**Reliability assessment of electrical equipment of metallurgical plant for separate sections in relation to types of technological production**

**Nosov Magnitogorsk State Technical University,  
Magnitogorsk, Russia**

At the large industrial enterprise which contains several types of technological lines for maintenance of continuous production process in a power grid complex of the metallurgical enterprise (ME) for realization of a normal mode of the power system operation it is necessary to provide quality of power supply which is defined by reliability and profitability. For evaluation of reliability and condition of electric grid complex it is required to perform analysis of disturbances in operation modes of power supply system of SE with voltage of 10–220 kV during 2007–2020 years. The analysis of the static data of outages showed that the main reasons of power supply failure are short circuits, imposing of several factors and unexplained circumstances, and 70 % of all failures are in cable lines, 25 % — overhead lines and 5 % — failures of power transformers. At present, the connection between electrical equipment and the technological objects being fed depends on their wear and tear.

On the example, the main technological processes of ferrous metallurgy production are considered sintering and rolling production, as the most energy-intensive and responsible consumers. It is necessary to identify categories of the most worn-out electrical equipment to develop a set of measures to improve reliability and reduce damages.

Keywords: reliability of electrical equipment, metallurgical enterprise, damage, emergency shutdown statistics, failure flow parameter, failure prediction.

**P. M. Korusenko<sup>1</sup>, S. N. Nesov<sup>2</sup>, K. E. Ivlev<sup>2</sup>**  
**Morphology, structure, and electrochemical properties of the MnO<sub>x</sub>@CNTs composite: a study of SEM, EDX, XPS, and CVA methods**

<sup>1</sup>Saint Petersburg State University, Saint Petersburg, Russia

<sup>2</sup>Omsk Scientific Center of SB RAS, Omsk, Russia

In this work, we carried out a comprehensive study of the morphology, chemical composition, electronic structure, and electrochemical characteristics of a nanocomposite based on carbon nanotubes (CNTs) and manganese oxide particles. The study of the electronic structure of the nanocomposite, performed by X-ray photoelectron spectroscopy (XPS), showed that manganese is in two chemically nonequivalent states in MnO<sub>2-x</sub> and in KMnO<sub>4</sub>. It has been established that manganese oxide is deficient in oxygen. In the course of electrochemical tests performed by the method of cyclic voltammetry (CVA), it is shown that the electrode based on the nanocomposite showed high arial capacitance values of 320 mF·cm<sup>-2</sup> at a potential scan rate of 5 mV·s<sup>-1</sup> and a low gravimetric capacitance of 14 F·g<sup>-1</sup>. With an increase in the potential scan rate, the specific capacitance of the nanocomposite significantly decreased relative to CNTs, which is due to a number of reasons: (i) insufficient porosity of the electrode surface; (ii) a decrease in the amount of MnO<sub>x</sub> nanoparticles in the electrode and their dissolution in the electrolyte during charge-discharge processes.

Keywords: carbon nanotubes (CNTs), nanocomposite, manganese oxide (MnO<sub>x</sub>@CNTs), morphology and electronic structure, electrochemical properties, supercapacitor.

## ELECTRONICS, PHOTONICS, INSTRUMENT ENGINEERING AND COMMUNICATION

**S. V. Biryukov<sup>1</sup>, L. V. Tyukina<sup>1</sup>,  
 A. V. Tyukin<sup>2</sup>**

**Measuring circuits of two double electro-induction spherical sensors of electric field strength of closed type constructively united into a single whole**

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

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

To control the levels of electric fields, electric field strength sensors are required. Currently, for these

purposes, the most promising are dual electric induction sensors, which are a constructive combination of two double sensors into one whole. There are two types of dual sensors with overhead, composite and separate sensing elements. The output signals of such sensors are electrical parameters such as charge, current and voltage. Studies have shown that electrical charge has the greatest advantage. To remove the charge from the sensor, it is recommended to use a current integrator (charge amplifier) as the primary measuring circuit. Secondary measuring circuits of the dual sensors considered in this work are used for averaging the signals of double sensors in order to reduce the error from the inhomogeneity of the electric field and form an output signal proportional to the field strength. It has been established in the work that sensors with overhead and composite sensitive elements allow to perceive the intensity of an inhomogeneous electric field with an error not exceeding +4,6 % in the spatial measurement range  $0 \leq a \leq 1$ . The work also determined the sensitivities of two types of dual sensors of the electric field strength.

Keywords: electric field strength, electric field strength sensor, single sensor, double sensor, two double in one, primary measuring circuits of sensors, error from field inhomogeneity, sensor sensitivity.

**S. V. Biryukov<sup>1</sup>,  
 L. V. Tyukina<sup>1</sup>,  
 A. V. Tyukin<sup>2</sup>**

**Calibration of double electroinduction spherical electric field strength sensor in a homogeneous field**

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

For measuring the strength of electric fields near high-voltage equipment, dual electroinduction spherical sensors, which are a constructive combination of two double sensors into one, are promising. Before operation of the sensors, they must be calibrated in a homogeneous ED. This process is time consuming, expensive and not safe. In the paper, the authors propose the idea of calibrating sensors with currents equivalent to the output currents of a sensor located in a real uniform field. For this, a current signal simulator has been developed, which is based on mathematical relationships obtained during the theoretical interaction of a sensor with a homogeneous ED. To test the proposed idea, the dual sensor is first tuned and calibrated according to the method described in the article to obtain static characteristics. Then, to confirm the correctness of the calibration, the sensor is placed in a real homogeneous electric field. In a homogeneous EC, static characteristics are taken from the sensor and compared with its static characteristics obtained after the current signal simulator. The results of the comparison showed a good match of the static characteristics. The discrepancy is no more than  $\pm 3\%$ . Since the experiments are carried out for evaluation, such an agreement of the static characteristics can be considered acceptable. A more careful adjustment of the measuring circuits of the dual sensor will reduce the error of the discrepancy between the static



characteristics to (0,5–1) %. The obtained results of the research allow us to confirm the adequacy of the theory underlying the calculations of dual electric induction sensors of the electric field strength.

Keywords: electric field strength, dual electric field strength sensor, sensor current signal simulator, homogeneous field generator.

**E. V. Leun**

**On the issue of achieving subpicometric resolution by acousto-optic two-channel laser displacement interferometer with two different frequency photodetectors**

**Lavochkin Association, Moscow region, Khimki, Russia**

The article discusses an acousto-optical (AO) heterodyne laser displacement interferometer (LDI) with two different-frequency photodetectors: high-frequency (HF) and low-frequency (LF) low-noise, working with «fast inaccurate» and «slow accurate» measuring channels, respectively.

The mode of operation of AO LDI at start-stop cyclic motions of objects is described, which provides high resolution at the initial and final stages of motions with low speeds of motion. A metrological analysis of the «slow accurate» channel is carried out taking into account the noise frequency characteristics of photodetectors with the formation of its so-called «optimistic» and «pessimistic» variants. Based on the metrological analysis carried out, the frequency ranges of the signal are determined, which allow achieving the resolution of AO LDI subpicometric values at low speeds.

Keywords: laser displacement interferometer, phase-locked frequency system, acousto-optic modulator, photodetector noise, signal jitter, picometer, small-phase meter.

**A. S. Gorbunov, M. V. Elfimova, Yu. N. Bezborodov**  
**Study of changes in color characteristics of steel under thermal exposure**

**Siberian Fire and Rescue Academy EMERCOM of Russia, Zheleznogorsk, Russia**

The article presents the results of studies of steel samples under thermal exposure, by measuring color characteristics using a model of color decomposition into RGB components. The data obtained can be used in the investigation of fires at objects made of steel building structures and objects made of steel. Thus, the specialist will be able to confirm his conclusions regarding the establishment of the source of the fire and the ways of its spread.

Keywords: RGB, thermal damage to steel, color characteristics, fire investigation.

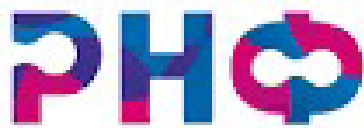
**O. I. Gordeev, V. A. Zakharenko**  
**The hardware and software complex for electromechanical equipment diagnostic**

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

The results of the development of the hardware and software complex for electromechanical equipment diagnostic by electrical power consumption parameters are presented. The connection of the prototype of the above-mentioned complex to the laboratory stand for vibration diagnostics of electromechanical equipment and the obtained possibilities for experimental research are described. The obtained experimental graphs of changes in the values of the main electrical power consumption parameters of the electric motor over time at different levels of load on the shaft of the stand are shown.

Keywords: electromechanical equipment diagnostic, hardware and software complex, spectral analysis, current diagnostics, vibration diagnostics.

## Конкурс РНФ малых отдельных научных групп



**Российский  
научный фонд**

Российский научный фонд извещает о проведении открытого публичного конкурса на получение грантов Фонда по приоритетному направлению деятельности РНФ «Проведение фундаментальных научных исследований и поисковых научных исследований малыми отдельными научными группами».

Гранты выделяются на осуществление фундаментальных и поисковых научных исследований в 2023–2024 годах по всем отраслям знаний классификатора РНФ.

Реализация проектов должна быть направлена на проведение исследований в целях развития новых для научных коллективов тематик (в том числе на определение объекта и предмета исследования, составление плана исследования, выбор методов исследования) и формирование исследовательских команд.

Руководитель проекта должен иметь не менее пяти различных публикаций в ведущих рецензируемых российских и зарубежных научных изданиях, опубликованных в период с 1 января 2017 года до даты подачи заявки. Руководитель проекта имеет право в качестве руководителя подать только одну заявку для участия в данном конкурсе. Количество проектов, финансирование которых осуществляется фондом через одну организацию, не ограничивается.

Размер одного гранта составляет до 1 500 000 рублей ежегодно.

Доля членов научного коллектива, непосредственно занятых выполнением научных исследований, в возрасте до 39 лет включительно в общей численности членов научного коллектива должна составлять не менее 50 процентов в течение всего периода практической реализации проекта. Размер ежегодного вознаграждения всех членов научного коллектива в возрасте до 39 лет включительно не может быть меньше 35 процентов от суммы ежегодного вознаграждения всех членов научного коллектива.

Общее число членов научного коллектива (вместе с руководителем проекта) должно составлять от 2 до 4 человек.

Заявка должна быть зарегистрирована в ИАС уполномоченным работником организации не позднее 17 часов 00 минут (по московскому времени) 15 июня 2022 года.

Итоги конкурса будут подведены до 30 ноября 2022 года.

Подробная информация на сайте РНФ в разделе «Конкурсы» <https://rscf.ru/upload/iblock/c65/0rgd1myftqp3qkct0zdl6nbq4pi692cd.pdf>

Организационно-методическое сопровождение конкурса осуществляет Отдел сопровождения научной деятельности (Г-205, тел. 65-33-66, [myugarkusha@omgtu.ru](mailto:myugarkusha@omgtu.ru)). Для подтверждения участия в конкурсе необходимо предоставить в отдел сопровождения научной деятельности заявку о намерении принять участие в конкурсе. Прием документов на конкурс будет осуществляться отделом сопровождения научной деятельности в срок до 6 июня 2022 г.