STUDY OF THE TEMPERATURE CONDITION OF AN ACTUATOR MADE OF A MATERIAL WITH A SHAPE MEMORY EFFECT

V.N. Zimin, G.N. Kuvyrkin, I.Yu. Savelieva, A.O. Shakhverdov

Abstract: a promising trend in the use of actuators made of materials with the shape memory effect is their use in large-sized transformable space structures. Currently, when creating mechanisms that include elements made of a material with a shape memory effect, experimental methods play a major role. Only the temperature field can act as a controlling effect on the active element made of a material with a shape memory effect. For the correct implementation of the process of opening a large-sized transformable structure, it is necessary to accurately simulate the operation of the actuator. In this regard, there is a need to study in depth the temperature conditions of the active element. The studies were carried out with an active element made of titanium nickelide, made in the form of a wire with a diameter of 1.5 mm. This paper presents the results of experimental studies of the temperature condition of the active element, as well as the calculation of the temperature condition in the Matlab software package. A study was conducted of temperature changes along the length of the active element with the shape memory effect, as well as temperature changes along its width. The results obtained will make it possible to make more accurate mathematical models of the functioning of the active element of an actuator for opening of large-sized space structures

Key words: temperature, actuator, shape memory effect, mathematical model, finite elements, opening, space structures

Acknowledgments: the work was supported by the Ministry of Science and Higher Education of the Russian Federation (project № FSFN-2023-0012)

CONTROL ALGORITHMS DEVELOPMENT OF MOBILE ROBOT WITH PERTURBATION COMPENSATION

A.S. Verkner, K.O. Gorlova, E.O. Guryanova

Abstract: the paper considers the structural problems associated with compensation of deterministic perturbations acting on a mobile robot. The result obtained in the work makes it possible to assert that in comparison with systems based only on feedback, the use of perturbation anticipation, cascade control in many cases has an advantage. The mathematical and computer models of the movement of a mobile robot for deterministic perturbations are described. The presented mathematical model, which has a simple structure and is convenient for solving various control problems, can be used for educational and methodological purposes. Based on the use of the principle of the internal model, the conditions for compensating the perturbation in the steady state are provided. Disturbance anticipation has been implemented in relation to this control object. An analytical design of cascade control has been made. A comparison of the studied structures of control systems is presented. A comparative analysis has been carried out and the effectiveness of each control principle has been investigated by means of numerical simulation. The presented control algorithms have shown their effectiveness in compensating the disturbance, and also improved the stability and speed of the system. The research results can be used in the development and testing of control systems that are subject to deterministic disturbances. A mobile robot of the "robot car kit" class is considered as a control object. Computer simulation was carried out in the MATLAB class environment

Key words: mathematical model of a mobile robot, computer model of a mobile robot, movement of a mobile robot uphill, disturbance compensation, internal model principle, disturbance anticipation, cascade control

DESIGN OF CONTROL SYSTEMS FOR ROBOTIC SYSTEMS BY MEANS OF A CAD SYSTEM

G.V. Petrukhnova, V.A. Trubetskoy, A.S. Tochilin

Abstract: the development and use of robotic systems are relevant, effective and justified. Modern data collection, storage and analysis tools are required to monitor the state of robots. Competent implementation of control procedures for robotic systems is one of the main conditions for ensuring the efficiency and reliability of their functioning. This article discusses a semi-autonomous robot controlled by a CAD system. The purpose of the article is to present the architecture of system for controlling a robot manipulator. In this task, the CAD system is a simulation-control environment in which three-dimensional models reflect the behavior of a physical device. The presented system includes an arbitrary robotic subsystem consisting of functional blocks, as well as a desktop application that displays a model of a controlled device. Each unit of the robotic subsystem can exchange information with other elements of the subsystem. The information exchange protocol is designed so that the system of modules with their internal addresses is deployed at the transport level. The internal address contains the device type and its unique number from among such devices. The intermodule exchange of information is determined by the session level of the protocol. The software implementation is based on the use of a DLL library with an API common to all such libraries. The protocol stack assumes the presence of several independent modules, and the data is distributed between them by the server. For an external client, there is only one entry point to the system – the server. Models of real devices are loaded into the system from files of open formats: OBJ, STL. Shaders are written for each format. The library developer can specify a set of types of sensors, drives, drives suitable for working with his device. This makes the system suitable for working with devices from an arbitrary set of modules with a known communication protocol. To add any new device for monitoring and control, it is only necessary to implement the protocol inside the embedded system, and then assemble the implementation of the part of the graphical system in the form of a dynamic library. Examples of practical use of the presented system are considered

Key words: robotics systems, OSI model, three-dimensional modeling, CAD system, shader, data exchange protocol, desktop application, Phong lighting model

APPLICATION OF CONVEYOR PROCESSING MODEL IN LOGISTICS PROBLEMS

I.I. Suprunov

Abstract: the problem of modifying the model and algorithm of additive sequential (conveyor) processing of a moving extended object is considered for the purpose of application in some problems of logistics. The conveyor processing algorithm in the initial version is associated with the problem of forced cooling of the hot strip and contains three modules. These modules correspond to the modes of passive cooling of the strip before entering the core, forced cooling in the core, and passive cooling after leaving the core until the moment of winding. The most important part of the algorithm is the module for calculating the operating modes of shower installations in the core. This module can be adapted for use in some logistics tasks related to scheduling the delivery (or receipt) of goods in the presence of a sequence of vehicles and a sequence of terminals. In the problem of delivery (or receipt) of goods, the capacities of vehicles and the capacities of terminals are specified. The capacity of the terminal is understood as the number of conventional units of cargo that can be unloaded (or received) at the same time in this terminal. Each vehicle performs unloading (or loading) sequentially in several terminals, while the selection of the corresponding active terminals from the total sequence of all terminals (drawing up a waybill) is determined by a modified version of the pipeline processing algorithm

Key words: conveyor processing, terminals, logistics

DEVELOPMENT OF A PROBLEM-ORIENTED SYSTEM FOR SOLVING OPTIMIZATION TASK OF MANAGING THE FLOW INCOMING APPLICATIONS

A.V. Dyatchina, S.A. Oleinikova, T.N. Nedikova

Annotation: the work is devoted to the development of methods and problem-oriented programs for the task of determining the best match between the flow of incoming applications and specialists who can fulfill them. In the classic version, this task is a task about assignments. The fundamental difference between the considered task and the known option is the use of several arbitrary criteria reflecting the quality of the chosen solution, the availability of a schedule of specialists servicing applications that came earlier, as well as time constraints on the performance of work. One of the combinatorial methods of discrete optimization, the method of simulated annealing, was chosen as an approach for developing the algorithm. It is advisable to use this method for complex NP-complete discrete optimization problems, to which the problem under study belongs. Special attention is paid to the development of a problem-oriented system, which is based on the practical implementation of the described algorithm. The structure of this system is developed, the database is designed, the main forms of the application are presented. In addition, the article presents the results of the proposed algorithm on test data. The developed algorithm and the problem-oriented system can be used at any enterprises and organizations in which it is required to solve the problem of distributing the flow of incoming applications to specialists from the point of view of a variety of criteria

Key words: optimization problem, problem-oriented system, multi-criteria optimization, annealing simulation method, assignment problem

DEVELOPING A PROTOTYPE OF SOFTWARE-HARDWARE SYSTEM FOR SYNCHROPHASOR MEASUREMENTS BASED ON GPS-DISCIPLINED ANALOG-TO-DIGITAL CONVERTER

V.A. Kazbanov, M.S. Kuritskiy, A.N. Aleshchenko, V.M. Aniskevich

Abstract: this article addresses the issue of a lack of software-hardware solutions for real-time digital monitoring of various grid parameters, it's generation and transmission subjects (power, phase shift, frequency, etc.). It has been analyzed that an effective response to a various distortions and failures of the grid a synchronization needed when measuring its parameters across different areas, considering that data transfer rates are fast and the grid itself is widespread. The study describes an effective method for solving such problems by developing and introducing new devices based on the synchrophasor measurement technology, that use time synchronization from Global Positioning Systems. It should be noted that foreign analogues of such devices are expensive, and their constructional details are closed. The result of this work is a complete prototype of a software-hardware complex for synchrophasor measurements based on GPS-disciplined ADC, which is a cheap, yet perspective and open analogue to many commercial solutions. A software, built from scratch, completely implements the processes of acquiring, processing and displaying measurement results to the end user on a webpage with an access from a local or a global network

Key words: syncrhophasor measurements, electrical energy industry, digital signal processing, microcontrollers, GPS/ GLONASS, software-hardware system, grid equipment diagnostic systems

STUDY OF IMPACT DEVICE TOOL OSCILLATIONS UNDER ASYMMETRIC LOADS

A.M. Slidenko

Abstract: a model of an impact device tool in the form of a constant cross section rod in the presence of asymmetric impulse loads is considered. The transverse and longitudinal oscillations of the tool are assumed to be independent under impulsive external loads. The load on the tool from the processed rock and additional load as a result of other uncertain factors are considered. The tool is considered as a cantilever beam with a rigid mount at one end when calculating transverse oscillations. The design model of longitudinal oscillations is represented by a rod with elastic and dissipative resistance at the end from the side of interaction with the striker. The impulse load is modeled by determining the initial speed in a small section of the tool and the short-term acting force in a given section of the tool. An initial-boundary value problem is formulated with inhomogeneous wave equations of the second and fourth orders, the right part of which models an instantaneous force on a certain part of the tool. The solution of the initial boundary value problem is found by the finite difference method and the Fourier method in the presence of only rigid resistance in the longitudinal direction. The Fourier method allows choosing rational parameters of the difference scheme. A difference scheme with weight coefficients is chosen. The solution of difference problems on each time layer is found by three-point and five-point sweep methods. The equivalence of determining the impulse load by two different methods is shown. The Fourier method and the finite difference method are implemented in a common computer program. The program allows you to determine various forms and frequencies of oscillations in the longitudinal and transverse directions and the distribution of stresses in the tool sections

Key words: impact device, tool, wave equations, cantilever beam, transverse oscillations, longitudinal oscillations, the Fourier method, boundary conditions, impulse load, difference scheme, sweep methods

FUNCTIONALITY OF THE AUTOMATED SYSTEM FOR THE DEVELOPMENT AND PRODUCTION CONTROL OF SOLID-STATE RELAYS

D.N. Trubitsyn, A.V. Koskin

Abstract: a variant of an automated production control system (APCS) is consideredю It combines the capabilities of electronic document management systems (EDMS), computer-aided design systems (CAD) and automated process control systems (APCS). The main functions and sets of documents used for automated production management at the stages of development of technical specifications (TOR), draft design, engineering design, prototype manufacturing and serial production are defined. Based on the tasks facing various production departments, a mode of access is proposed to various types of production documents, taking into account the need for documents to be approved by various production departments (technological, metrological, quality control department (QCD) and so on). The possibility of automatic generation of some documents is analyzed, if all the necessary information for their release is in other electronic documents included in the proposed workflow system. Considered the exchange of documents between different departments in the process of doing work. The necessary auxiliary functions of this system are considered, such as storing backup copies of documents and converting documents into widely used formats. The possibility of combining the system with the APCS system, and the need for functionality that ensures the conversion of documents into files suitable for the APCS system are considered. In conclusion, it was concluded that this system will reduce labor costs and reduce the time required for the development and manufacture of products, by automating the issuance of individual documents, as well as reducing the time required for the exchange of documents. In addition, integration with automated process control systems will significantly increase the automation of production, practically excluding a person from the direct management of production

Key words: APCS, EDMS, CAD, APCS solid-state relays, functions and documents of APCS

BANDGAP REFERENCE VOLTAGE SOURCE FOR A DOMESTIC TECHNOLOGICAL PROCESS

A.V. Rusanov, L.V. Sopina, A.V. Bunina

Abstract: the article proposes two IP blocks of operational amplifiers (op-amps) built on n-channel and p-channel differential pairs. Op-amps are universal blocks on the basis of which you can build many different electronic devices. Currently, op amps are widely used, both in the form of individual chips and as IP blocks as part of more complex integrated circuits. The developed IP blocks are intended for use in integrated circuits of linear voltage stabilizers as error amplifiers. In voltage regulators, the error amplifier plays a key role by comparing the reference voltage to the output (or part of the output voltage) voltage and drives the pass element to ensure this equality. The description of the electrical circuits of amplifiers, the main electrical characteristics, the results of modeling are presented, the features of the development of the integrated circuit topology are indicated. The op amps are developed on the basis of the domestic BiCMOS technological process with design standards of 3 μm. The development of the scheme and topology was carried out in a specialized system for automated design of integrated circuits. To model the circuit, certified mathematical models of semiconductor devices were used. The developed layouts of the op-amp have passed verification, consisting of checking compliance with design standards (Design rule check, DRC), restoring the electrical circuit from the layout and comparing the layout with the original circuit (Layout vs Schematic, LVS)

Key words: reference voltage source, IP block, integrated circuit, microcircuit, ION

THE MAIN PROBLEMATIC ISSUES AND MODERN APPROACHES TO COUNTERING SMALL-SIZED RECONNAISSANCE AND STRIKE UNMANNED AERIAL VEHICLES

D.G. Pantenkov, V.P. Litvinenko, A.N. Glushkov

Abstract: as the analysis of the events of 2022-2023 years has shown, the use of small-sized reconnaissance and reconnaissance-strike unmanned aerial vehicles of small and light classes in armed conflicts and when damaging critical infrastructure facilities has become widespread. This is easily explained by the availability of their purchase, their very insignificant cost on the one hand and wide functionality on the other hand. Modern UAVs of small and light class are capable of being in the air from several tens of minutes to several hours, to carry out continuous monitoring of objects of interest, to conduct radio and radio-technical reconnaissance of specified areas, to survey the underlying surface, to issue target designation for the target attack to multiple rocket launchers, to adjust the accuracy of hitting projectiles of shock means, to relay information to remote to its recipients, act as shock drones or kamikaze drones. In fact, modern conflicts have moved into the stage of intellectual confrontation between operators of robotic complexes and systems, including complexes with UAVs of various classes and purposes. The article is a continuation of a whole series of works, including by other authors, devoted to countering small-sized UAVs, shows the calculated quantitative ratios of the required level of radiated energy depending on the distance to the object of impact in the case of the use of electronic warfare and functional damage to avionics, conclusions are drawn

Key words: unmanned aerial vehicle, small class, counteraction, basic methods, electronic warfare, functional defeat, radio communication, navigation, efficiency, automated complex

USING MEMS SWITCHES FOR REALIZATION OF ACTIVE PLANAR ANTENNA UDA-YAGI

E.A. Ishchenko, S.O. Raspopov, A.S. Tupitsina, I.A. Chernoivanenko, S.M. Fedorov

Abstract: the article considers the possibility of using MEMS switches in the design of a planar Uda-Yagi antenna to control the characteristics of the radiation patterns. The simulation of the problem under study was performed based on the use of SPICE models of equivalent circuits of a MEMS switch in both active and off modes. The results obtained show that the use of MEMS switches makes it possible to ensure high efficiency of the antenna, while it is possible to provide control over the characteristics of the antenna patterns, since additional directors are connected based on switching MEMS keys. To improve the simulation accuracy in the off mode, MEMS switches were also replaced with equivalent circuits. The study has confirmed that MEMS switches have low resistance in the active mode and high isolation in the off mode. During the simulation, the Uda-Yagi planar antenna was studied, which had thirteen directors, of which twelve had two MEMS switches in their design to turn the directors on and off. Based on the simulation, it was obtained that the antenna has an efficiency factor from 11.8 to 14.1 dB, while the efficiency over the entire operating frequency range is more than 65%, and thanks to the use of MEMS switches, it is possible to provide a quick connection of additional directors in the Uda-Yagi planar antenna, which increases the directional antenna properties

Key words: active antenna, Uda-Yagi antenna, MEMS switches, SPICE model

INFLUENCE OF NOISE ON THE FREQUENCY MEASUREMENT ERRORS FROM DISCRETE SAMPLES OF A HARMONIC SIGNAL BY THE METHOD OF MOMENTS

M.A. Alrubei, A.D. Pozdnyakov

Abstract: algorithms for measuring the deviation of the frequency of harmonic signals based on the use of an array of discrete samples, fast Fourier transform (FFT) and interpolation are known. The method of moments makes it possible to obtain a weighted average estimate of the position on the frequency axis of the energy spectrum peak taken as the measurement result. In this work, the determination of the limits of applicability of the method of moments is considered by estimating the methodological error due to the influence of the FFT frequency grid step, the type of window function used, the number of spectral lines taken into account, and the duration of the signal sampling interval. The experimental study is based on the method of semi-natural simulation in the Matlab 2016 environment with computer generation of a selected number of samples of a test harmonic or polyharmonic signal during real processing of the obtained data in the presence and absence of noise. The results of studying the influence of the number of samples, the number of spectral lines taken into account, the signal-to-noise ratio for the Nuttall, Chebyshev, and other windows are presented. Recommendations to optimize frequency control parameters are given. The influence of the number of samples, the number of spectral lines taken into account, the signal-to-noise ratio for the Nuttall, Chebyshev, Blackman, Kaiser, Hanna, Triangular, Planar vertex, Parsen, Blackman-Harris windows are presented. Recommendations in order to optimize the parameters of frequency control are given. A comparison of errors for different window functions with a signal-to–noise ratio of 60 dB shows that with 16 counts and taking into account three spectral lines, the Triangular window with an error of about 1E-03 is the best, and the Nuttall window with an error of 1E-02 is the worst. With 2048 counts and taking into account seven spectral lines, the best is the Nuttall window with an error of 1E-09, the worst is the Triangular window with an error of 1E-06. Analysis of the simulation data showed that when using the method of moments, it is first necessary to estimate what maximum amount of samples can be obtained and what number of spectral lines to use in calculations, and only after that choose the appropriate window. The correct choice of the type of window function allows you to reduce the error by an order of magnitude

Key words: method of moments, frequency, harmonic signal, reading, error, time window

TECHNIQUE OF THE SUBSTANTIATION OF DEMANDS TO THE ANALOG PART OF THE DIGITAL RADIORECEIVER RECEPTION SECTION

R.I. Burov, A.I. Grevtsev, V.I. Zimarin, V.V. Kapitanov

Abstract: when designing of an analogue part of a digital radioreceiver reception section based on superheterodyne principle, with reference to narrow-band signals, there is a necessity to use the methodical apparatus, allowing to consider agency of sensitivity, a noise factor, coefficient of amplification of an analogue section, a digitization at an analogue-digital conversion, superposition of spectra in the course of a digitization and sampling of face values of intermediate frequencies. The paper is devoted to the development of a technique for substantiating the requirements for the analog part of the receiving path of a digital radio receiver. The novelty of the presented approach is the consideration of the variety of factors that affect the structure of the elements of the analog path, based on the requirements for the characteristics of the developed digital radio receivers. It is shown how, at the design stage, the preliminary selection of the structure of the received frequency path, amplifying devices, based on the conditions of multi-signal selectivity, the choice of the minimum value of the first intermediate frequency, taking into account the suppression of interference in the side channels of the first frequency conversion, frequency values sampling and nominal value of the second intermediate frequency, as well as block diagrams of the paths. The proposed approach allows justifying the requirements for the construction of the analog part of the receiving path of a digital radio receiver, as well as for the parameters of its elements

Key words: the digital radioreceiver, section of accepted frequency, section of intermediate frequencies, sensitivity, selectivity

STUDY OF THE INFLUENCE OF FILTER CAPACITORS ON THE PERFORMANCE OF CONTROLLED METAMATERIAL

S.M. Fedorov

Abstract: this article investigates the nature of the influence of decoupling capacitors on the performance of a phase shifter based on a controlled metamaterial built in the form of an electromagnetic crystal at the nodes of which switching pin-diodes are placed. Decoupling capacitors were added to the design of the phase shifter to filter the DC component of the electric current that drives the pin diodes. Graphs of realizable phase shifts and the level of insertion losses obtained using mathematical modeling are presented. The use of a controlled metamaterial makes it possible to achieve a change in the phase value of the reflected wave in a wide frequency band ranging from 0 to 360 degrees, while the frequency dependences of the phase corresponding to different sections of the reflection plane have a regular character. In addition, reflections from the structure of the controlled metamaterial with switched off switches are insignificant, and due to the isotropy of the metamaterial, the polarization of waves can be arbitrary. It seems promising to use optically controlled MEMS and NEMS switches, in which the contacts are closed as a result of light pressure on one of the device plates. This type of switching elements has a high degree of achievable isolation, reaching 70 dB in the closed state and low attenuation (hundredths of a decibel) in the open state. Also, it is possible to use a photocontrolled semiconductor as a switch, which is characterized by low conductivity in the absence of illumination and high conductivity when it is illuminated

Key words: reflective phase shifter, decoupling capacitors, controlled metamaterial

METHOD FOR CONTROL OF THE EFFECT OF PULSED INTERFERENCE ON A RAILWAY RADIO TRANSMISSION SYSTEM

I.V. Sviridova, R.N. Horoshaylov, D.V. Lyalin

Abstract: train-to-track radio communication systems transmit the information necessary for train operation between on-board radio equipment and the associated radio infrastructure along the track, such as train control, voice dispatch, commands, operational information, and monitoring data. In high-speed rail environments, electromagnetic interference (EMI) poses a serious threat to radio communication systems between the train and the tracks and can lead to critical safety issues for rail vehicles and even passengers. Given the complex development scenario of high-speed rail, it is important to monitor the impact of interference to ensure the quality of the Radio Communication System between the train and the tracks. On the one hand, radio communication systems between the train and the tracks operate in a complex electromagnetic environment where temporary interference coexists constantly and changes dramatically during the movement of the train. On the other hand, various radio technologies have been used for railway applications, including forward error correction codes to protect against electromagnetic interference. Thus, this article proposes a new approach to assessing the impact on radio transmission, based on the joint statistical characteristics of time-varying electromagnetic interference. This approach uses a dynamic mapping model of the effective signal-to-interference plus noise ratio to establish a relationship between airborne radio block error performance and overall interference statistics using a mutual information metric. Simulation of radio transmission using turbo coding and low-density parity-check coding under various interferences shows that this approach is effective for estimating the degradation of the transmitted signal in direct error correction coding due to electromagnetic interference with different characteristics

Key words: electromagnetic effect, amplitude probability distribution, pulse duration distribution, radio transmission between train and tracks

RESEARCH OF THE PARAMETERS OF THE COOLING SYSTEM OF THE TABLE OF A DEVICE FOR ADDITIVE SHAPING BY A PLASMA ARC IN A DYNAMIC VACUUM ENVIRONMENT

V.V. Kuts, A.N. Grechuhin, D.A. Pavlov, I.A. Chernyshov

Abstract: the article is devoted to studying the issues of designing the cooling system of the working table of a device for additive shaping of products by a plasma arc in a dynamic vacuum environment. The design parameters of the desktop cooling system, namely the diameter and number of cooling channels, are determined. The conditions for the operability of the cooling system are determined. To build mathematical dependencies to determine the design parameters of the desktop cooling system, a series of experiments was carried out using the computer simulation method. The study was carried out using the Flow Simulation module of the SolidWorks system. To construct equations for determining the temperature of the coolant, the temperature of the desktop, the initial data were simulated using the Statistica program. Equations are obtained that express the mathematical dependence of the temperature of the coolant and the surface of the working table on the design parameters of the cooling system - the diameter of the cooling channels and the number of channels for cooling the working table. The criterion for optimizing the design parameters of the cooling system of the working table of the device is determined - the minimum volume of coolant in the cooling system. Based on the data obtained, rational design parameters of the designed cooling system of the desktop were determined, which ensure the operability of the device for additive shaping of products by a plasma arc in a dynamic vacuum environment: the number of cooling channels is 4, the diameter of one cooling channel is 8 mm

Key words: additive technologies, shaping, plasma welding, finite volume method

TECHNOLOGY OF ABRASIVE TOOLS MANUFACTURING ON THE BASIS OF PHOTOPOLYMER-ABRASIVE COMPOSITE, IN CONDITIONS OF SINGLE AND SMALL-SCALE PRODUCTION

D.A. Goloburdin, A.M. Kozlov

Abstract: grinding is one of the most common methods for processing critical surfaces of parts in modern mechanical engineering. Among the large number of factors affecting the grinding process, one of the most important are the characteristics and properties of the abrasive tool. In connection with the introduction of new structural materials into production, the development and production of modern abrasive tools are one of the priority tasks. The technology of manufacturing an abrasive tool using SLA 3D printing technology (stereolithography) is described. The main technological stages of manufacturing an abrasive tool according to the proposed technology are given, a description of the equipment used in the work, software (CAD systems, systems for generating programs that control the operation of a 3D printer), as well as consumables and sample printing modes are presented. The possibilities of the proposed technology are presented, in particular, the manufacture of tools with complex geometry of working surfaces, variable geometry from the periphery to the center of the tool, as well as with variable characteristics, for example, with different grain sizes of abrasive material. The advantages and disadvantages of the proposed technology are considered, the results obtained are analyzed. The results of regression analysis are presented, on the basis of which the dependence of the layer exposure time parameter on the density of the photopolymer-abrasive composition is derived

Key words: additive technologies, 3D printing, photopolymer-abrasive composite, SLA technology, grinding tools